Indian Science Congress Association

Silver Jubilee Session, 1938

AN OUTLINE OF THE FIELD SCIENCES OF INDIA

Edited by

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PREFACE.

The idea of publishing an outline of the Field Sciences of India, on the occasion of the Silver Jubilee Meeting of the Indian Science Congress Association, was suggested by Mr. W. D. West, the Honorary General Secretary of the Association and was readily accepted by its Executive and General Committees. The original intention of the author of the scheme was to help the foreign delegates to a proper appreciation of the manifold field problems involved in the study in India of such subjects as Meteorology, Oceanography, Geology, Botany, Zoology, Ethnology, Agriculture, Animal Husbandry and Archæology, and to enable them to make the best use of their short sojourn in this country. The publication was also intended to help the delegates to study any particular problem, in case they wished to do so, on the spot. The very title of the publication, however, denotes its scope, and those who may wish for more information on any of the subjects dealt with in the volume should refer to the detailed treatises made use of by the authors of the respective chapters.

It was a pleasant duty to collect the necessary material for this work. The readiness with which the authors responded to the invitation to contribute their respective chapters was most helpful. To fulfil its original purpose the work had to be produced within the short period of about 6 to 7 months, and it is hoped the readers will realize that under these limitations it was not possible to mould the various chapters to any general plan. Efforts were, however, made to bring about a certain amount of uniformity in the presentation of the material in each chapter and the Editor is greatly indebted to the authors who very kindly agreed to the suggestions made in this respect.

To make the text intelligible to general readers, each chapter is suitably illustrated. The number of illustrations, however, had to be restricted owing to the limited funds available. The coloured Orographic Map of India, which forms the frontispiece, should enable the readers not only to locate the various places referred to in each chapter, but will also give a clear idea of the physical features of the country, a knowledge of which is absolutely essential for a proper study of the field sciences.

It is hoped that the work as now presented will not only serve as a guide and a companion to all those who may wish to employ their leisure hours in the pursuit of the study of Field Sciences in this country, but will also enable the specialists in various branches of science to appreciate the problems of sister sciences. A composite publication of this nature is likely to have a wide influence in creating a broader outlook in the study of 'Science' as a whole, and may help to bring about a certain amount of

co-operation between workers in different branches which is so desirable for the advancement of science in these days of specialization and which is one of the main objects of the annual meetings of the Indian Science Congress Association.

To the students of science in India this publication is likely to be of great value and it is hoped that, in due course, it may stimulate among them a desire for work in the field. The true significance and value of the various subjects dealt with in this Outline can only be appreciated through an extensive study in the field and in this respect such a publication was hitherto a desideratum.

To achieve the above mentioned objects the Executive Committee of the Association has agreed to distribute copies of this publication, free of charge, to all Ordinary and Sessional Members of the Congress and to charge members of the other categories only a nominal price. Separates of the various chapters have also been published and will be available for sale almost at cost price.

The special thanks of the Editor are due, and are gratefully tendered, to Dr. B. Prashad and Mr. W. D. West for their kind help in various ways. The Science Congress Association is indebted to the Bombay Natural History Society, the Imperial Council of Agricultural Research, and the Director-General of Archæology in India for the loan of the majority of the blocks used to illustrate the chapters on Vegetation, Fauna, Agriculture and Animal Husbandry, and Archæology. Several other illustrations are reproduced by kind permission of the Director-General of Observatories, the Editor of the *Geological Magazine*, the Inspector-General of Forests, the Editor of the *Indian Forester*, the Imperial Council of Agricultural Research, and the Home Department of the Government of India. The sources of the various borrowed illustrations are fully acknowledged along with their explanations. The thanks of the Association are also due to the Surveyor General of India for supplying copies of the Orographic Map of India at a specially reduced rate.

The Association is indebted to the authorities of the Baptist Mission Press, Calcutta, especially to Messrs. P. Knight and N. A. Ellis, for their co-operation and help in the publication of the volume so expeditiously and in a manner characteristic of the reputation of this press.

Museum House,
Calcutta.
November, 1937.

SUNDER LAL HORA

CONTENTS.

THE WEATHER OF INDIA.[1]

By

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Contents.

Contrasts and Seasons

India presents as great contrasts in meteorological conditions as any area of similar size in the world, and furnishes the typical large-scale example of the alternation of seasons known as monsoons. The contrasts are striking. In the north-west lies the great Rajputana desert with average annual rainfall of less than 5 inches; in the north-east is Cherrapunji with an average annual rainfall of 430 inches. The observatory at Dras in Kashmir has recorded a temperature as low as −49°F.; that at Jacobabad has several times registered 126° and over. Hill stations in the Himalayas, such as Simla, may be shrouded in cloud for days together in September with humidities of 100 per cent., but in November may be overrun with air of practically zero humidity. The mean *annual* range of temperature at Cochin in South India, 20°F., is less than the *daily* range at many stations in North India and only about one-third of their annual range. During the winter third of the year the general flow of the surface air strata is from land to sea and thence over the Indian Seas as a *north-east monsoon*; it is a season of winds of continental origin and great dryness. The summer third of the year sees a complete reversal of this condition in a flow from sea to land of the moist winds of the *south-west*

[1] Largely a reprint of Chapter XVI of '*Souvenir—The Indian Empire*', (Calcutta, 1927), Congress of Far Eastern Association of Tropical Medicine. Also compare Chapter III in Vol. I, *Imperial Gazetteer of India,* (1907).

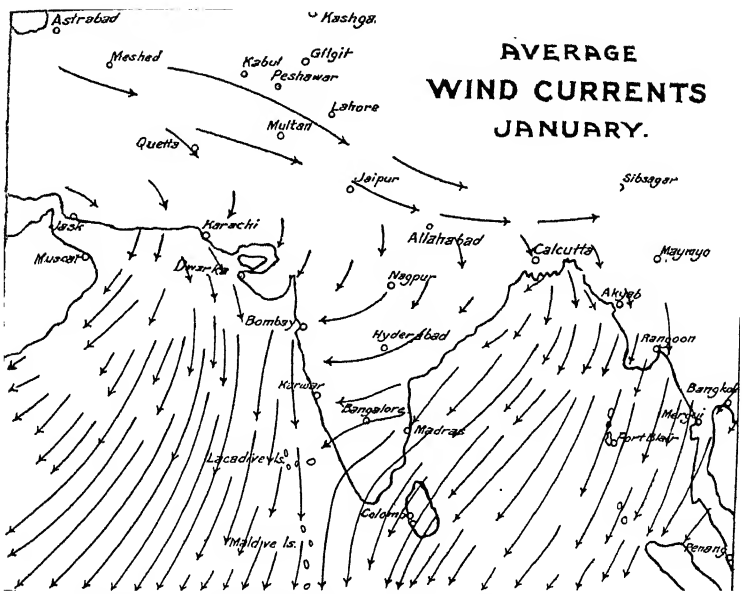
monsoon, which consequently is a season of much humidity and cloud and frequent rain. Between these principal seasons of the year are the transitional periods of the *hot weather* months, April and May, and of the *retreating south-west monsoon*, October and November. The causes determining the monsoon currents are many and complex but the fundamental cause is certainly the difference of temperature in the winter and summer months respectively between Southern Asia on the one hand and the Indian Ocean and China Seas on the other.

North-east Monsoon

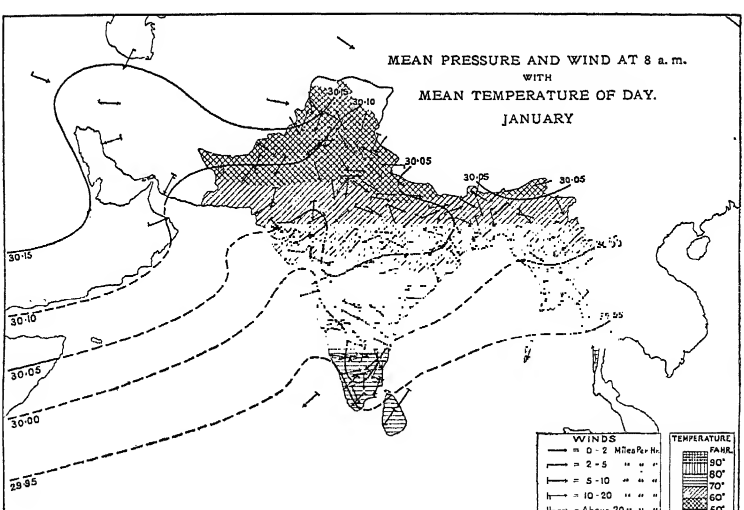
The North-east Monsoon is fully established over the Indian land and sea areas in the beginning of January (text-fig. 1), when Asiatic temperatures are at their lowest. There is then a belt of high pressure with anticyclonic conditions stretching from the West Mediterranean to Central Asia and North-east China. Clear skies, fine weather, low humidity, large diurnal range of temperature, and light northerly winds are the usual features of the weather in India during this period, broken only at intervals by weather disturbances which pass eastwards across Persia and Northern India, often into China. At Calcutta unfortunately the general fine weather of this season, with its evening and morning inversion of temperature in the lower atmosphere, often favours the formation of an evening blanket of smoke and morning mist. The western disturbances are ordinarily less intense than, but similar in type to, the depressions of European latitudes. The precipitation accompanying them is small in amount, but very important for the winter crops. Some in their eastward passage give light rains over the whole of Northern India, while others which confine their activity to the extreme north give moderate to heavy rain in the Punjab plains and heavy snowfall in the higher Himalayas. The disturbances are attended with marked temperature effects, a rise occurring in front of them, while in the rear unusually dry, clear weather prevails as a rule with stronger and cooler westerly winds. During this period of the year, rainfall is greatest in the north-west and decreases towards the south and east; dry weather prevails generally in the Peninsula and South Burma. The distribution of temperature (text-fig. 2) is almost similar to that of rainfall, weather being colder in the north-west than in the east and south.

Hot weather period

The hot weather period of March to May is one of continuous increase of temperature and decrease of barometric pressure in North India, of continuous decrease of temperature in the South Indian Ocean and adjacent land areas of Africa and Australia and of intensification of the southern anti-cyclonic high pressure area. There occurs a steady transference northward of the area of greatest heat in India, and simultaneously of the equatorial belt of low pressure of the winter season. In March the highest day temperatures, about 100°F., occur in the Deccan; in April the area of



TEXT-FIG. 1.—Sketch of average wind currents in January.

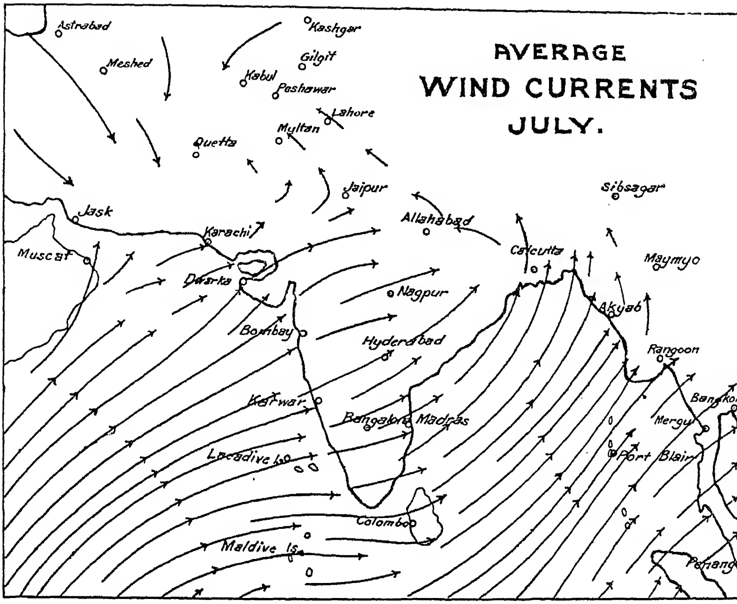


TEXT-FIG. 2.—Pressure, temperature and wind directions in January.

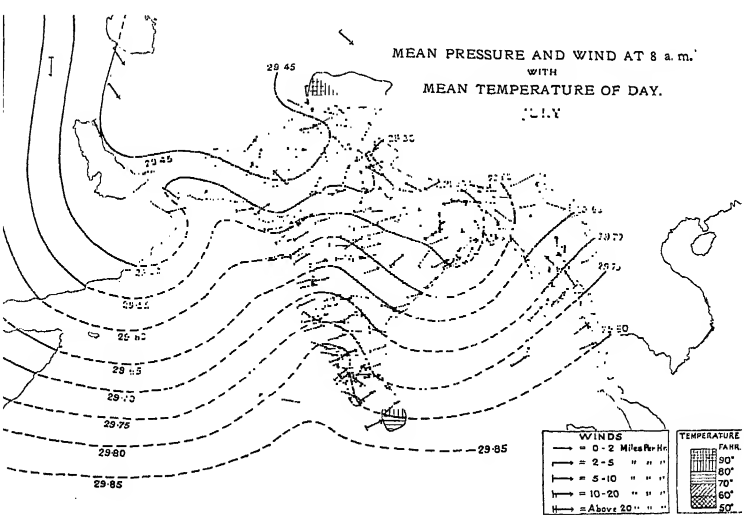
highest day temperatures, from 100° to 110°, lies over the south of the Central Provinces and Gujarat; while in May the seat of greatest heat is Northern India, and especially the north-west desert, where day temperatures of 120°F. or over are not infrequent. The area of lowest pressure also lies then over North-west India, with a trough stretching thence to Chota Nagpur. A local air circulation, with this trough as centre, exists over India and causes indraughts from the adjacent seas of southerly winds across the Bengal coast and of north-westerly winds across the Bombay coast. The land and sea winds give rise to large contrasts of temperature and humidity and consequently to violent local storms, especially in Bengal, where they are usually called "nor'-westers". These are sometimes of tornadic intensity and very destructive.

South-west Monsoon

Towards the end of May the air circulation over India becomes more and more vigorous, until, almost abruptly, the south-east trade winds from south of the equator are induced northwards into the Arabian Sea and Bay of Bengal and caught up in the Indian circulation. In most years this humid current, or the *south-west monsoon*, bursts on the Malabar coast during the first five days of June. It gradually extends northwards and is usually established over most of the Indian area by the end of June (text-fig. 3). The orographical features of India are of great importance in modifying the flow of the monsoon currents and the distribution of monsoon rainfall. The mountain ranges to the east and north of India are equivalent to two sides of a box, through the other two sides of which the monsoon currents stream. The southerly or Bay of Bengal current is naturally deflected by the two sides of the box northwards through Burma, and then westwards up the Gangetic Plain. The Arabian Sea current surmounts the Ghats on the west coast, causes copious rain there, advances over the Deccan and Central Provinces, and generally meets the Bay of Bengal current along the line of the trough of low pressure, which normally extends from Orissa to North-west India. Depressions which both intensify the monsoon rainfall and tend to concentrate it in their vicinity occasionally form in the north of the Bay and move along this trough (text-fig. 4). Further the trough is not stationary but moves north or south of the normal position and affects the rainfall distribution as it moves. Consequently the monsoon period is not one of continuous rain in any part of India. Bursts of general rain alternate with breaks partially or generally as the case may be. The pulsatory character of this action and of the rainfall precipitation is one of the most important features of the monsoon period meteorologically, as it is also economically for the proper growth of the crops. On the average, it may be said that the strength of the currents and the accompanying rainfall increase from June to July and remain steady till about the end of August. The monsoon then begins to retreat from Northern India. The table on page 6 shows



TEXT-FIG. 3.—Sketch of average wind currents in July.



TEXT-FIG. 4.—Pressure, temperature and wind directions in July.

the general distribution of rainfall month by month from May to October over the Indian land area :—

	Inches
May	3·1
June	7·9
July	11·2
August	10·3
September	7·0
October	3·3
TOTAL ..	42·8

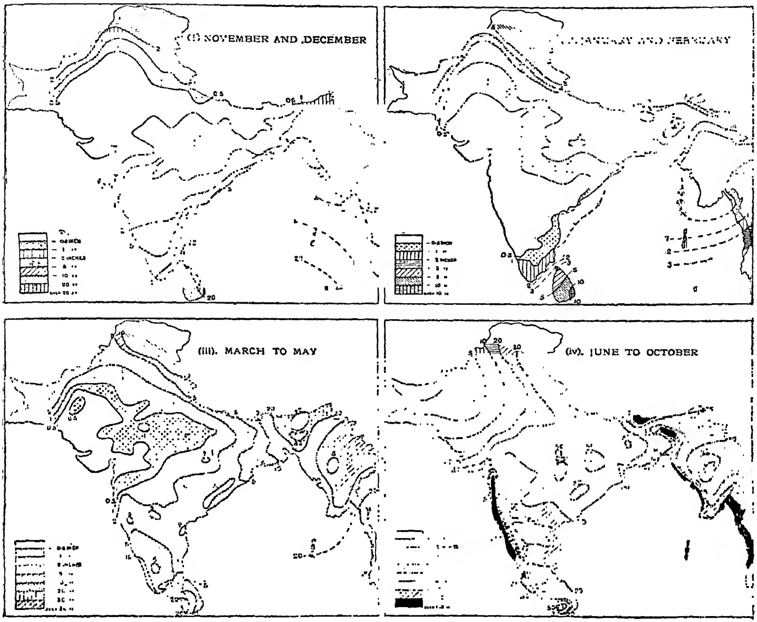
There are four important variations from the normal in the monsoon rains over the country; firstly, the beginning of the rains may be delayed considerably over the whole or a large part of India; secondly, there may be prolonged break or breaks lasting over the greater part of July or August; thirdly, the rains may end considerably earlier than usual, and lastly the rains may persist more than usual in one part of the country and consistently shun another. Consequences of the third variation are occasionally very serious and have been disastrous in the extreme in the famine areas, while the fourth constitutes the most common abnormality.

Retreating South-west Monsoon

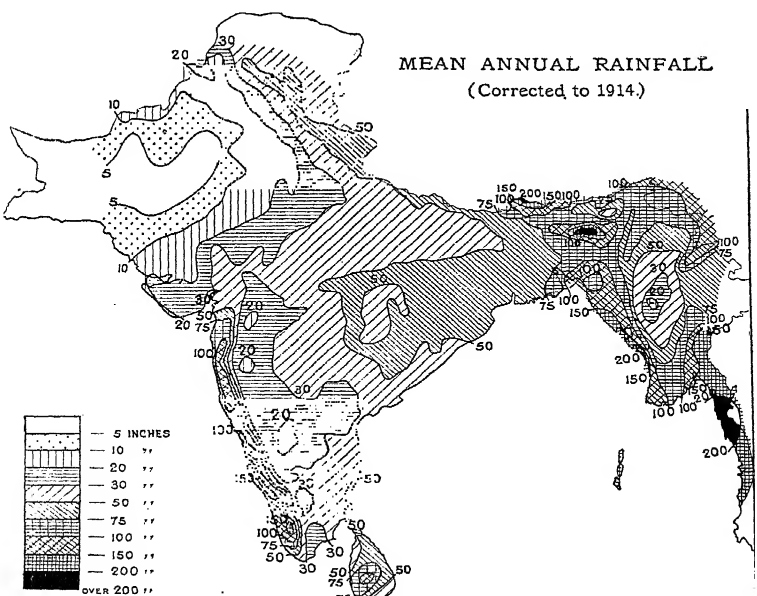
The second half of the wet season forms a period of transition leading up to the establishment of the conditions of the dry winter season. This transition begins in the early part of October and is usually not completed until mid-December. The Arabian Sea monsoon current retreats southwards from Rajputana, Gujarat and the Deccan by a series of intermittent actions. The Bay of Bengal current retreats similarly down the Gangetic Plain. The low pressure conditions previously prevailing in North India are obliterated by October, are transferred to the centre of the Bay at the beginning of November and to the south of the Bay by the beginning of December. By the end of that month the belt of low pressure usually passes out of the Bay limits into the equatorial belt where it forms a permanent feature of the meteorology of the Indian Ocean during the next five months. Similar conditions obtain in the Arabian Sea also. This retreat is associated with dry weather in Northern India but with more or less general rain on the coastal districts of Madras and over the eastern half of the Peninsula, where October and November are often the rainiest months of the year.

Rainfall Variations

From the foregoing description as well as from table A, it will be understood that the distribution of rainfall over India depends largely on its orographical features (text-fig. 5). If the hills and mountains of India were effaced, the country would receive much less rainfall and would not be able to support its present



TEXT-FIG. 5.—Mean Seasonal Rainfall.



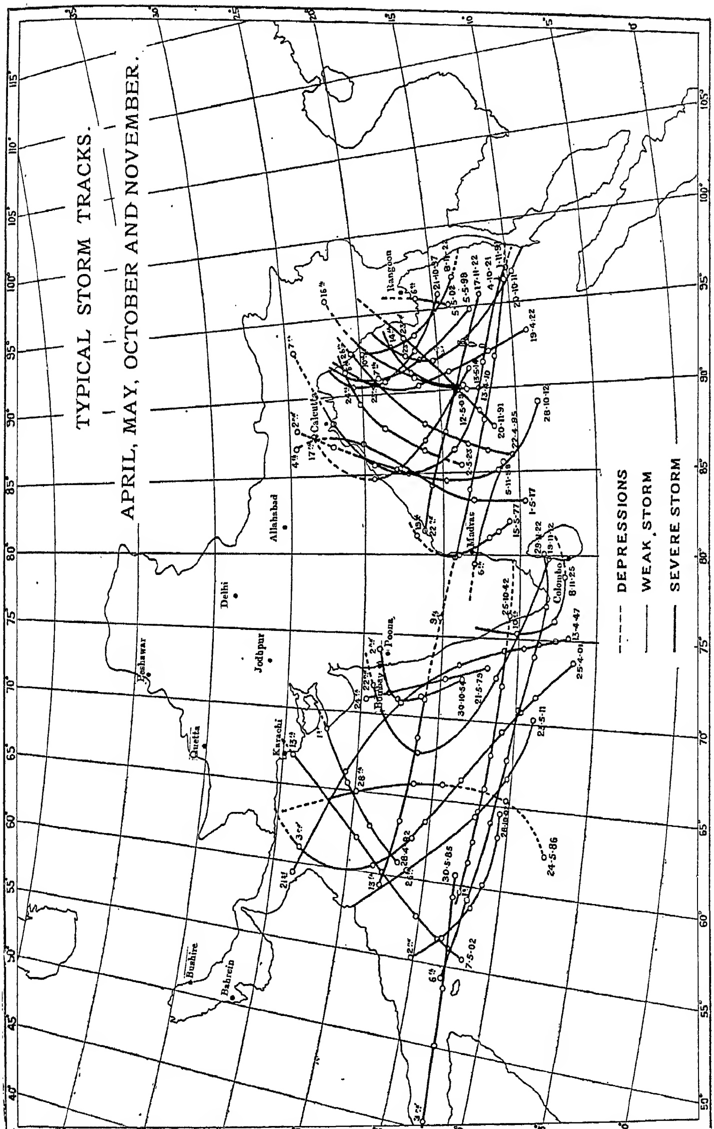
TEXT-FIG. 6.—Mean Annual Rainfall.

population. It will also be seen that the rainiest season in most provinces is the monsoon period, June to September; that rainfall during the cold weather is scanty but essential and economically important for the production of wheat crops over Northern India; and that the important rains in South-east Madras are those of October to December. Stress has also been laid on the great variability of monsoon rainfall in time and space in any one year. The variations in the amount of precipitation received from year to year are also surprisingly large. The average annual rainfall (text-fig. 6) of the Indian region, excluding Burma, is 42 inches and variations from this normal as great as +12 inches and −11 inches occurred in 1917 and 1899 respectively. Long breaks in the monsoon or an abrupt finish of the rains is disastrous to crops and produces droughts or famines. The droughts occur particularly in the interior districts, the percentage variability of annual rainfall being 100 per cent or even more in North-west India and parts of the Deccan. Droughts due to the failure of winter rains affect mostly the Punjab and the Gangetic Plain. The result of a drought may be scarcity or famine, either local or widespread. Famine, however, though once 'the bogey of the Indian administrator' is no longer the nightmare that it was, because the effects of a drought of any particular intensity have been minimised in the past 60 years by the famine-relief system, the spread of irrigation, the network of railways and improvements in dry-farming.

On the other hand, tracts of country are sometimes deluged with rain and suffer distress through excessive flooding. The heavy downpours occur chiefly near the tracks of the cyclonic depressions of the monsoon months or of the cyclones that occasionally advance inland from the Bay of Bengal or Arabian Sea. A fall of 10 inches to 20 inches in a day is by no means a rare occurrence. The heaviest ever recorded in the plains in 24 hours is 35 inches at Purnea in Bihar.

Cyclones

At a time when the general meteorology of India was unknown, Henry Piddington laid the foundations of our knowledge of the storms of the Indian Seas and introduced the word *cyclones* to connote them. In these storms, oval or circular in shape, the air moves in converging spirals in a left-handed direction against the hands of a clock. The winds become fiercer and fiercer as the centre is approached and reach hurricane force near it. In the innermost central zone of some ten miles diameter the wind suddenly falls off to a calm or light air, and the barometric pressure there often marks an inch, and sometimes as much as two inches, below normal. Cyclones generally die away soon after they reach land, but in the coastal districts which they touch may cause great havoc through high winds, torrential rain and, most destructive of all in low-lying districts, storm waves (text-fig. 7). The latter are due to the huge masses of sea-water swept forward by the storms and, when aided by a high



TEXT-FIG. 7.—Tracks of Cyclones in Indian Seas.

tide, may inundate low-lying land to a depth of 20 feet. The storm wave accompanying the Bakarganj cyclone of 1876 was one of the most destructive on record; about a hundred thousand people were drowned in half-an-hour on the alluvial flats of the Meghna, while an equal number died from epidemics of fever, cholera and other diseases, which almost invariably follow a storm wave. The principal cyclone months in both the Arabian Sea and Bay of Bengal are May, October and November. They may also occur in April, September and December, and, particularly in the Arabian Sea, in June on the advancing front of monsoon air.

Temperature and Climates

Temperature is perhaps, next to rainfall, the most important feature of meteorological observations in India from the economic standpoint. During one part of the year from January to May or June the increase of temperature by solar action is greater than the loss by radiation and other actions, and hence temperature rises more or less steadily in conformity with the increasing elevation of the sun. During the remainder of the year, the balance is the other way and temperature steadily decreases from June or July to December. Though, in most countries July and August are as hot as, or hotter than, June, the similar phenomenon is prevented in India by the cloud and rains of the south-west monsoon. The annual variation of temperature is small in the extreme south and increases rather rapidly northwards; proceeding along the east and west coast of India, it is twice as great at Bombay and Rangoon as in Malabar and over four times as great at Karachi. It is from eight to ten times as great at stations in the North Deccan and Northern and Central India and is absolutely greatest in the most inland of the driest tracts, including Upper Sind and the Punjab. The difference between the minimum and maximum temperatures on a day, called the diurnal range, is much smaller in the wet than in the dry season and at coastal stations than in the interior. It is about 10°F. on the west coast of the Peninsula, and rises to 30°F. on the mean of the year in the Punjab and Upper Sind.

As already indicated in the opening paragraph, different parts of India exhibit very great diversity in respect of their climatic features. Northern or extra-tropical India alone, in its most easterly and most westerly provinces, in Assam on the one hand and in Sind on the other, presents us with the greatest possible contrast of dampness and dryness, a contrast greater than that of the British Isles and Egypt; and when, further, we compare the most northerly province, the Punjab, with the most southerly, such as Travancore or Tenasserim, we have in the former a continental climate of the most pronounced character, extreme summer heat alternating with winter cold that sometimes sinks to freezing-point, and in the latter an almost unvarying warmth in conjunction with a uniformly moist atmosphere, that is especially characteristic of the shores of a tropical sea. In addition to this heterogeneity on the plains,

there is a further variety due to the hills. Indeed, from a sanitary point of view and as health resorts, the climates of hill stations deserve special mention. These stations are situated along the Himalayas and on the Ghats in the Peninsula. In all cases their atmosphere is cooler and damper than that of the neighbouring plains; but while those in the North-West Himalaya are subject to great vicissitudes of heat and cold, dryness and dampness in the course of the year, those of Southern India and Ceylon are comparatively equable, and their fine clear season is shorter than at the northern stations, and by no means so dry. In table B are given the temperature data for a few hill stations, as well as for selected stations in the plains.

(The India Meteorological Department publishes *Daily Weather Reports* in Poona, Calcutta, and Karachi; the *Indian Monthly Weather Report*; *Annual Summary*; and seasonal forecasts of monsoon and winter rains. The scientific work of the department is published in departmental *Memoirs*, *Scientific Notes* and in various atlases and handbooks).

TABLE A.

Monthly and Annual Normal Rainfall by Divisions.

Divisions	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sep.	Oct.	Nov.	Dec.	Year
Lower Burma	0·12	0·23	0·55	1·42	12·30	25·79	29·77	27·50	17·61	7·85	2·71	0·54	126·39
Upper Burma	0·10	0·21	0·42	1·29	5·98	8·11	7·35	8·63	8·03	5·55	1·82	0·47	47·96
Assam	0·67	1·53	4·00	9·00	12·08	18·23	18·74	16·83	12·50	5·66	0·90	0·35	100·49
Bengal	0·34	0·95	1·67	3·25	7·64	14·62	15·14	14·26	10·89	5·08	0·79	0·16	74·79
Orissa	0·44	1·17	1·08	1·38	3·31	9·83	13·01	13·00	8·96	4·88	1·52	0·22	58·80
Chota Nagpur	0·77	1·15	0·93	0·70	2·13	8·97	12·91	13·77	8·10	2·92	0·39	0·14	52·88
Bihar	0·42	0·69	0·47	0·60	2·27	7·78	12·36	12·51	8·80	2·32	0·29	0·09	48·60
United Provinces, East ..	0·63	0·55	0·32	0·19	0·67	4·78	11·55	11·33	6·87	1·87	0·19	0·22	39·17
United Provinces, West ..	0·96	0·89	0·61	0·30	0·68	4·06	11·47	11·14	5·96	0·88	0·15	0·36	37·46
Punjab, East and North ..	1·21	1·02	0·91	0·56	0·62	2·02	6·22	6·37	3·30	0·38	0·13	0·44	23·18
Punjab, South-west ..	0·50	0·53	0·64	0·52	0·42	0·81	2·47	2·56	1·11	0·10	0·08	0·21	9·95
Kashmir	3·71	3·54	4·60	3·45	1·93	2·53	7·26	7·86	3·60	1·05	0·48	1·97	41·98
N.-W. Frontier Province ..	1·28	1·19	1·89	1·54	0·77	0·86	2·58	3·16	1·18	0·33	0·28	0·54	15·60
Baluchistan	1·18	1·19	1·24	0·68	0·27	0·30	0·98	1·00	0·25	0·15	0·26	0 62	8·12
Sind	0·11	0·18	0·18	0·10	0·25	0·34	1·64	2·20	0·96	0·14	0·02	0·07	6·19
Rajputana, West ..	0·19	0·23	0·18	0·16	0·44	1·31	3·43	4·07	2·04	0·32	0·08	0·10	12·55
Rajputana, East ..	0·37	0·31	0·24	0 17	0·52	2·62	8·31	8·14	3·96	0·52	0·16	0·22	25·54
Gujarat	0·09	0·10	0·07	0·03	0·33	5·15	12·61	8·11	4·64	0·91	0·20	0·04	32·28
Central India, West ..	0·38	0·30	0·16	0·15	0·47	4·78	10·52	10·97	5·21	0·80	0·41	0·16	34·31
Central India, East	0·56	0·63	0·33	0·22	0·43	4·50	12·04	12·49	6·36	1·17	0·35	0·21	39·29

Berar	0·39	0·35	0·33	0·24	0·54	6·05	9·12	6·91	5·80	1·57	0·57	0·39	32·26
Central Provinces, West ..	0·65	0·71	0·59	0·31	0·59	7·39	13·44	12·91	7·60	1·82	0·56	0·30	46·87
Central Provinces, East ..	0·46	1·11	0·60	0·73	0·79	9·32	15·27	14·93	7·59	2·25	0·40	0·29	53·74
Konkan	0·10	0·05	0·06	0·36	1·55	25·31	39·09	23·99	12·53	4·30	1·01	0·13	108·48
Bombay Deccan ..	0·15	0·08	0·15	0·63	1·35	5·22	7·85	5·44	5·61	3·02	1·01	0·28	30·79
Hyderabad, North ..	0·16	0·25	0·37	0·51	0·73	5·51	8·00	7·23	8·10	2·30	0·77	0·36	34·29
Hyderabad, South ..	0·18	0·24	0·42	0·81	1·02	4·33	6·24	6·31	6·82	3·02	1·06	0·22	30·67
Mysore	0·12	0·13	0·31	1·46	3·58	4·80	7·15	5·23	5·18	5·30	2·42	0·45	36·13
Malabar	0·92	0·57	1·50	3·84	7·39	23·82	21·50	12·16	7·85	11·33	7·36	1·86	100·10
Madras, South-east ..	0·98	0·47	0·51	1·29	2·53	1·56	2·19	3·61	4·48	7·10	7·47	3·38	35·57
Madras, Deccan ..	0·20	0·14	0·21	0·62	1·67	2·36	3·21	3·91	5·75	4·18	2·18	0·41	24·84
Madras Coast, North ..	0·38	0·39	0·50	0·93	2·10	4·91	6·61	7·07	6·96	6·75	3·69	0·85	41·14

TABLE B.

Mean Maximum and Minimum Temperatures in Fahrenheit.

Stations	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sep.	Oct.	Nov.	Dec.	Highest Maximum	Lowest Minimum
Karachi (Drigh Road)	78·3 *51·2*	80·5 *54·5*	89·5 *62·1*	94·7 *71·5*	94·8 *77·5*	94·0 *82·0*	91·2 *81·1*	87·8 *78·6*	89·8 *76·2*	95·1 *68·7*	89·7 *59·2*	80·8 *52·7*	116·3	31·4
Jodhpur ..	76·9 *50·5*	80·6 *53·3*	90·9 *62·7*	100·2 *72·5*	106·0 *79·8*	103·8 *82·2*	97·5 *80·3*	93·1 *77·7*	94·8 *75·5*	96·4 *67·8*	88·8 *58·6*	79·6 *52·2*	121·3	28·1
Delhi ..	70·0 *47·9*	74·6 *51·7*	86·0 *61·6*	97·9 *72·8*	104·0 *80·2*	103·3 *83·6*	94·9 *81·1*	92·4 *79·8*	93·0 *77·1*	91·6 *68·4*	82·2 *56·7*	72·9 *48·9*	118·0	32·5
Agra ..	74·2 *43·8*	78·5 *46·9*	90·2 *55·8*	101·7 *67·8*	107·5 *77·0*	105·0 *83·4*	95·0 *80·2*	91·7 *78·9*	93·1 *75·6*	92·9 *62·7*	85·5 *49·5*	76·9 *44·4*	120·3	33·9
Allahabad ..	74·4 *48·0*	79·5 *51·9*	91·9 *61·7*	102·8 *72·0*	106·6 *79·6*	102·1 *82·7*	92·8 *79·8*	90·0 *78·6*	91·5 *76·9*	91·1 *67·5*	83·4 *55·3*	75·7 *47·7*	119·8	34·1
Jubbulpore ..	77·5 *48·6*	81·5 *52·4*	91·8 *60·5*	100·8 *70·2*	105·3 *78·5*	97·8 *78·9*	86·7 *75·0*	84·6 *74·0*	87·2 *72·8*	87·7 *64·2*	82·0 *53·2*	77·0 *46·7*	114·8	31·9
Patna ..	72·7 *50·9*	77·5 *54·2*	89·5 *63·9*	99·0 *73·3*	99·7 *77·7*	95·7 *79·8*	90·5 *79·8*	89·1 *79·4*	89·5 *78·8*	88·4 *72·8*	81·7 *61·0*	74·1 *51·8*	114·4	36·3
Calcutta ..	77·5 *55·6*	82·3 *60·3*	91·0 *69·4*	95·5 *75·7*	94·6 *77·6*	91·3 *78·8*	98·6 *78·7*	87·8 *78·5*	88·2 *78·1*	87·4 *74·5*	82·2 *64·7*	77·0 *56·0*	108·2	44·2
Tezpur ..	73·6 *52·4*	76·0 *55·7*	82·6 *61·8*	83·4 *67·1*	86·9 *72·3*	88·8 *76·6*	89·2 *77·6*	89·0 *77·7*	88·6 *76·5*	85·8 *71·1*	80·5 *61·4*	74·5 *53·5*	98·1	42·8
Mandalay ..	84·5 *56·6*	90·3 *60·1*	98·1 *68·3*	102·4 *77·3*	99·8 *79·0*	94·8 *78·6*	94·7 *78·6*	93·2 *77·9*	93·1 *77·1*	92·0 *74·7*	87·7 *67·9*	83·5 *59·4*	113·6	45·1

Akyab ..	80·8 *59·3*	84·3 *61·2*	88·5 *68·5*	91·3 *75·3*	90·5 *77·7*	86·0 *77·5*	84·6 *77·0*	84·6 *76·9*	86·4 *77·4*	87·3 *76·2*	84·7 *70·9*	80·7 *63·1*	100·1	47·3
Rangoon ..	88·6 *64·9*	92·3 *66·5*	95·9 *71·2*	98·0 *76·1*	91·7 *77·2*	86·4 *76·4*	85·3 *75·8*	85·0 *75·8*	85·9 *76·0*	87·6 *75·8*	87·5 *72·7*	87·1 *67·4*	106·4	55·3
Bombay ..	82·9 *66·7*	82·9 *67·2*	85·8 *71·6*	88·5 *75·7*	90·8 *79·3*	88·3 *78·4*	85·4 *76·5*	84·9 *75·9*	85·3 *75·5*	88·7 *75·4*	89·2 *72·3*	86·4 *68·5*	100·0	55·9
Nagpur ..	83·5 *55·6*	88·5 *59·6*	97·4 *67·2*	104·8 *75·7*	108·6 *81·8*	98·9 *79·0*	88·1 *75·3*	86·8 *74·6*	89·1 *73·8*	90·6 *68·3*	85·6 *60·0*	81·7 *54·2*	117·7	39·4
Ahmadabad ..	84·8 *57·7*	87·8 *59·5*	96·9 *67·2*	104·3 *74·4*	107·4 *79·2*	101·3 *80·9*	93·1 *78·5*	90·0 *76·8*	92·9 *76·1*	97·3 *72·4*	92·9 *65·5*	86·4 *59·3*	117·8	36·0
Poona ..	86·1 *53·3*	90·6 *55·2*	97·1 *62·1*	101·1 *68·9*	98·8 *73·0*	89·0 *74·0*	82·8 *71·9*	81·7 *70·5*	84·6 *69·1*	89·4 *66·5*	86·5 *58·9*	84·7 *53·0*	110·0	38·8
Hyderabad, Deccan (Begumpet). ..	84·2 *59·9*	89·7 *64·2*	96·7 *70·1*	101·2 *76·2*	103·1 *80·0*	94·5 *76·1*	87·6 *73·3*	85·8 *72·5*	86·4 *72·3*	88·4 *69·4*	84·5 *63·2*	82·4 *58·3*	111·9	47·3
Bangalore ..	80·8 *57·5*	86·2 *60·2*	91·1 *64·8*	93·5 *69·4*	91·7 *69·2*	84·9 *66·9*	82·2 *66·0*	82·0 *65·8*	82·3 *65·6*	82·1 *65·2*	79·8 *62·2*	78·9 *58·5*	100·8	45·8
Madras ..	85·2 *67·3*	87·1 *68·0*	89·5 *71·7*	92·4 *77·1*	97·9 *80·9*	98·3 *80·6*	95·3 *78·5*	93·7 *77·2*	92·7 *76·6*	89·6 *74·6*	85·7 *71·9*	83·9 *69·3*	113·0	57·5
Waltair (Vizagapatam)	80·8 *67·9*	83·8 *71·1*	87·3 *74·7*	89·7 *78·3*	92·0 *80·8*	91·2 *80·2*	89·0 *78·6*	88·8 *78·2*	88·4 *78·1*	88·0 *76·4*	84·3 *72·7*	80·8 *68·1*	111·4	59·6
Mangalore ..	89·2 *70·6*	88·6 *72·3*	90·1 *75·7*	91·7 *78·4*	91·3 *78·7*	85·3 *74·6*	83·9 *74·1*	83·7 *74·1*	84·5 *74·1*	86·1 *74·5*	88·2 *73·4*	89·3 *70·8*	100·1	59·8
Trivandrum ..	84·0 *72·3*	85·6 *73·7*	87·6 *76·5*	88·0 *78·2*	86·7 *77·9*	83·1 *75·6*	82·2 *74·8*	82·5 *74·8*	83·1 *75·0*	83·0 *74·9*	82·8 *74·1*	83·3 *72·9*	93·5	63·0
Quetta ..	50·1 *30·4*	52·5 *32·8*	63·1 *40·3*	73·4 *48·0*	84·7 *55·5*	92·0 *62·1*	93·7 *68·1*	91·9 *65·6*	85·8 *54·1*	74·5 *42·8*	64·1 *34·7*	54·9 *31·0*	103·9	3·0

Mean Maximum and Minimum Temperatures in Fahrenheit.

Table B (continued).

Stations	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sep.	Oct.	Nov.	Dec.	Highest Maximum	Lowest Minimum
Peshawar ..	63·4 *40·8*	66·2 *43·8*	74·5 *52·1*	84·9 *60·4*	96·8 *70·2*	104·8 *77·3*	102·2 *79·8*	98·2 *78·5*	94·8 *71·4*	87·9 *60·3*	76·5 *48·9*	66·6 *40·5*	121·6	24·7
Lahore ..	68·9 *40·2*	72·4 *43·8*	82·9 *52·9*	95·0 *62·8*	103·9 *71·8*	106·2 *78·7*	99·9 *79·7*	97·3 *78·4*	97·5 *72·7*	94·6 *59·2*	83·4 *46·8*	72·9 *39·8*	120·3	29·2
Rawalpindi ..	62·7 *38·1*	65·1 *41·3*	75·0 *50·3*	86·3 *59·1*	97·9 *68·3*	103·6 *75·7*	97·9 *76·8*	93·9 *75·4*	93·4 *69·1*	88·8 *56·6*	77·5 *44·2*	66·8 *37·4*	118·0	23·9
Simla ..	47·5 *35·2*	48·4 *35·6*	56·5 *43·1*	66·3 *50·3*	73·6 *57·4*	75·0 *59·6*	71·3 *58·9*	68·7 *59·2*	68·7 *56·3*	64·4 *51·4*	58·4 *43·9*	50·1 *39·2*	94·4	17·1
Ootacamund ..	65·6 *43·0*	67·4 *44·0*	70·0 *47·8*	71·7 *51·5*	70·2 *52·4*	64·3 *52·3*	62·1 *52·0*	62·9 *51·7*	64·4 *51·1*	64·6 *50·5*	63·6 *48·0*	64·8 *44·3*	78·0	30·5
Kodaikanal ..	62·0 *46·7*	64·1 *47·5*	66·1 *50·5*	68·2 *53·5*	67·9 *54·6*	64·2 *53·1*	61·9 *52·1*	62·4 *51·8*	62·1 *52·0*	61·8 *51·1*	60·7 *49·2*	61·6 *47·4*	78·0	37·1
Darjeeling ..	47·3 *35·1*	48·9 *36·1*	56·5 *42·3*	62·5 *48·4*	64·6 *52·3*	66·2 *56·5*	66·8 *58·0*	66·5 *57·6*	65·4 *55·9*	61·7 *50·1*	55·6 *42·8*	49·4 *36·7*	80·1	19·9
Mussooree ..	48·3 *37·3*	50·1 *37·7*	60·4 *45·3*	71·1 [illegible]	77·8 [illegible]	76·9 [illegible]	71·2 *69·7*	69·0 *59·9*	68·3 *57·2*	64·9 *51·4*	57·8 *45·5*	51·2 *40·1*	93·3	21·0
Pachmarhi ..	[illegible]	75·2 *51·0*	84·1 *59·*[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	74·8 *67·0*	77·5 *66·2*	79·0 *59·5*	74·2 *51·0*	70·8 *45·8*	105·0	30·0

THE OCEANS ROUND INDIA.

By

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Contents.

Introduction.

Until Geologists are able to come to some final conclusion egarding the past history of the earth it is impossible for the eanographer to formulate a definite theory concerning the gin of any of the great oceans of the present day. In this ect the Indian Ocean presents a particularly difficult problem g to the diametrically opposed views held by two schools of t. Biologists and Geologists in the past have not hesitated forward theories regarding the previous existence, and sub- t disappearance below the sea, of large areas of land in order ccount for a similarity in either the fossil or the living fauna and flora of lands that are now separated by wide stretches of sea and ocean. According to this school of thought, practically the whole of the region that is now the Indian Ocean and the area to the North of it was at the close of the Palæozoic Era, in Permo-carboniferous

times, occupied by two separate masses of land, the great continent of Angara, covered by the 'Gigantopteris' type of flora, stretching from east to west across the northern part of the hemisphere and the corresponding southern continent of Gondwana, characterized by the 'Glossopteris' flora, extending from Australia through Peninsular India and South Africa on to South America; between these two great continental masses ran a comparatively narrow sea that stretched from east to west uniting the Atlantic and Pacific Oceanic areas. At the close of the Mesozoic Era the great continent of Gondwanaland is supposed to have broken up, large areas foundering beneath the ocean, so that Australia, India, South Africa and South America became separated, the last completely; but India and Africa are supposed to have been still connected by an isthmus bridge, to which the name 'Lemuria' has been given, that followed a somewhat zig-zag course and the line of which is to the upholders of this theory still indicated by the position of Madagascar, the Seychelles, Mauritius, Réunion and the Chagos, Maldive and Laccadive Archipelagoes. Similarly, on the east side of India a large area of land, traversed by a mountain belt to which the name Madras Mountain belt has been given, is supposed to have extended eastward, possibly as far as the Andaman Islands, and occupied the area that is now the Bay of Bengal. In Permian times this land area together with Peninsular India formed, according to this view, an elevated region that drained northwards and was bounded on its east side by a great sea that extended northwards from Tenasserim to Assam and then westwards to the Punjab. In the Jurassic epoch this eastward extension of the Indian Peninsula, still traversed by the Madras mountain belt which by now had been considerably eroded, is supposed to have undergone subsidence and sank beneath the sea, thus giving rise to the fore-runner of the Bay of Bengal. About the same time the central part of the great continent of Angara is also supposed to have subsided, so that a great sea then extended from north to south and united the Arctic Ocean with the great tropical ocean that had drowned the greater part of Gondwanaland.

According to the second view, that was put forward by Wegener and is known by the name of the 'Drift theory', all the great continents of the present day were originally parts of one vast land mass, that later became split up into fragments; gradually these masses drifted apart, leaving the ocean basins as we see them to-day.

Whichever school of thought we may follow, at the close of the Mesozoic Era the Indian Ocean was composed of a northern and a southern part, in a manner that very closely resembled the Atlantic and Pacific Oceans of the present day, while from east to west a circum-terrestrial sea, the Tethys, passed to the north of Arabia and India, terminating in what is now the Bay of Bengal, and thus connected the Atlantic with the Indian Ocean;

further to the south-east there was a wide and probably deep connection between the Indian and Pacific Oceans, passing between Asia and Australia. There was thus a highway, not only from east to west, or *vice versa,* but also from north to south, along which the marine fauna and flora could extend from ocean to ocean so long as they were capable of surviving the differences of temperature and the competition of other already established forms and species.

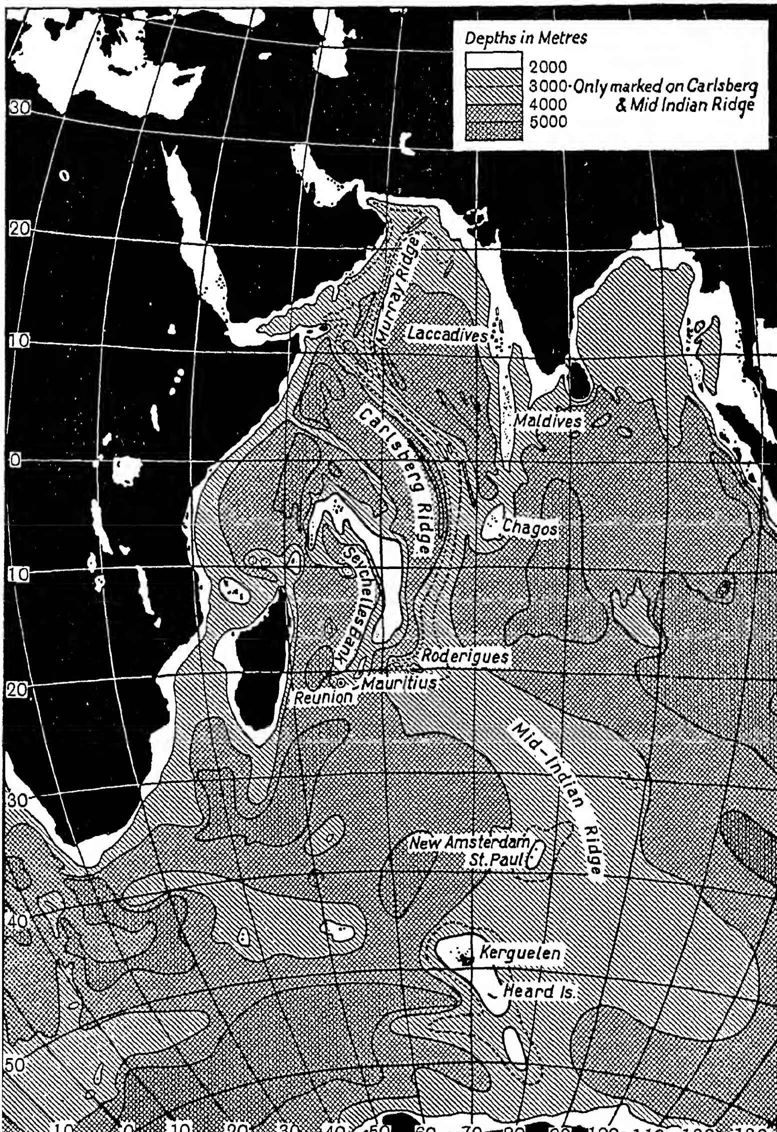
At the commencement of the Kainozoic Era, in Eocene and Miocene times, the great circum-terrestrial Tethys Sea began to be slowly but surely interrupted by the gradual uprising of the great Alpine-Himalayan mountain range; at first this interruption was but slight, taking the form of scattered islands, but as the upheaval continued the sea became transformed into a series of lagoons or a chain of more or less land-locked lakes, the original sites of which are perhaps indicated at the present day by the great petroleum-bearing regions; and finally even these were filled in. At the same time the upheaval of the Malayan arc caused a great obstruction to the free passage between the Pacific and the south-east part of the Indian Ocean. At or about the same period the gradual upheaval of the central Asian plateau caused the obliteration of the northern part of the Indian Ocean, so that to-day the only traces of its original vast extent are to be found in the Gulf of Oman and the Persian Gulf, and the great lakes of Asia, the Caspian Sea, the Aral Sea, etc. How far towards the south this upheaval of the Asiatic continent affected the Indian Ocean is not yet determined; but it seems probable that at the close of the Miocene a mass of land occupied the area between India, Arabia and north-east Africa, so that at that time there was as yet no Gulf of Aden or Red Sea, though these were beginning to be formed by the gradual development of the great African Rift, extending in a zig-zag direction from north to south between Palestine and Syria, then between Egypt and Arabia, and finally down the east side of Africa where the great African Lakes lie at the present day. Similarly, it has been suggested that even as late as Miocene times a vast tract of land once again extended eastward from India to the neighbourhood of the Andaman Islands, so that the Bay of Bengal was again obliterated.

Topography. (Figure 1).

At the present day India, with the island of Ceylon lying off its southern point, forms a triangle of land thrusting southwards into the Indian Ocean and thus dividing its northern area into two parts, the Bay of Bengal on the east and the Arabian Sea on the west. Each of these areas is again subdivided by a range of islands into a main area and a subsidiary region; to the east of the Bay of Bengal the curved chain of the Andaman and Nicobar Islands forms the

western boundary of the Andaman Sea basin and on the south-west of India the straight north-south line of the Laccadive, Maldive and Chagos Archipelagoes forms the western limit of the Laccadive Sea. Each chain of islands marks the line of a great submarine mountain range, but there is this great difference between the two; in the Andaman-Nicobar chain the islands are themselves the topmost peaks of the range, whereas in the Laccadive, Maldive and Chagos Archipelagoes the islands are composed entirely of coral that has grown up and now covers the mountain peaks, the actual topmost points of the range being at some and possibly a great depth below the surface. In the course of this growth the coral has here formed one of the finest series of atolls and lagoons in the world.

Running from north to south down the Bay of Bengal to the west of the Andaman-Nicobar Islands is a submarine ridge, named Carpenter's Ridge, that rises from the sea-floor up to about 2,280 metres or less and having water of some 3,650 metres on either side of it. It is probable that this ridge arose simultaneously with the Andaman arc and that both are parts of the Malayan arc that arose in Eocene-Miocene times contemporaneously with the Alpine-Himalayan system. To the east of the Andaman-Nicobar Islands lies a volcanic range that is in all probability Tertiary in age and is continuous with the series of volcanoes of Sumatra and Java; in the Nicobar region this volcanic range is inextricably blended with the non-volcanic range of the Andaman arc but further to the north the two ranges diverge and the volcanic range trends towards the north-east, its course being indicated possibly by 'Invisible Bank', that lies just to the east of Little Andaman Island and almost reaches the surface, and certainly by the bank from which the nearly extinct volcano Barren Island arises, while the extinct volcano Narkondam rises from the sea-floor as a western outlier: finally, this volcanic range runs through Burma between the Irrawaddi and Salween valleys, past the recently extinct volcano Mount Popa and on into the Shan States and Yunnan. The fact that Barren Island still possesses a warm spring, while Mount Popa has according to tradition only recently become extinct, suggests that the whole of this part of the volcanic range was active in comparatively recent times. It would seem probable that the Andaman Sea itself is of comparatively recent origin and that originally it extended much further to the northward. The geological features of the Irrawaddi valley indicate that this region was slowly but surely, if irregularly, undergoing subsidence and this is in all probability true of the whole Andaman Sea basin. This subsidence appears to have affected the Andaman-Nicobar chain for the topmost peaks of the range commence with a height of some 8,000 feet above sea-level at Chypotong in the Arakan Range but fall to only 150 feet above sea-level on Batti Malv in the Nicobars and then rise again to



TEXT-FIG. 1.—Bathymetric Chart of the Indian Ocean.

(Reprinted from *Geol. Mag.*, LXXIV, 1937, after slight modification.)

12,000 feet at Sinobong in Sumatra. Further eastward examination of the sea-floor has revealed the presence of an interrupted line of rock that runs almost parallel with the present coast of Burma and that lies at a depth of about 141 metres at the northern end but gradually sinks, as we trace it southward, till at its southern end near the island of Sumatra in Lat. 8° 52′ N., Long. 96° 29′ E. it is covered by 417 metres of water ; several isolated banks rise nearly to the surface, thus Heckford Bank lies at a depth of only 13 metres, Coral Bank at 20 metres and Roe Bank at 15 metres, but at no point does the ridge actually break the surface. It seems probable that this is an arc of the Malayan Ranges that has become submerged since its upheaval in Tertiary times.

The nature of the bases on which the Laccadive, Maldive and Chagos Archipelagoes respectively are perched can only be guessed, since there is no true land in any island of these groups ; indeed it seems possible that the two extremes of the chain may have had different origins, for the recent work of Lieut.-Col. E. A. Glennie, R.E., D.S.O., of the Survey of India, on the geodetic character of the Laccadive and Maldive groups has proved that this differs in the two Archipelagoes, a positive variation being found in the former and a negative in the latter. Glennie draws the conclusion that the Laccadives are perched on an upthrust, that may be a continuation of the Aravalli Mountain Chain, the oldest mountain range in India and dating back to the Permo-Carboniferous Era ; the Maldives he believes, on the other hand, to be situated on a deep-seated down-warping, and the actual ridge may perhaps be volcanic in origin, as suggested by Murray and others. Whatever the nature of the basic rock of these ridges may be, it is not improbable that they were once a part of the mainland and became separated off from India and Ceylon by a fault, the line of which is now marked by the Laccadive Sea, and, if we accept the Drift Theory of Wegener, were left behind and became submerged when India drifted away towards the north-east.

To the west between India and Africa recent topographical investigations have revealed the existence of a great submarine mountain chain, the Carlsberg Ridge, that rises from the sea-floor, with a depth of some 5,300 metres on its south-west side and of 5,120 metres on the north-east, to a height of at least 12,000 feet, soundings as shallow as 1,550 metres having been obtained in about Lat. 1° N. and again in about Lat. 10° N. This great ridge, which appears to be double throughout the greater part of its length, two high ridges enclosing between them a deep gulley in which the depth is some 3,380–3,660 metres, commences in the vicinity of the island of Socotra and Cape Guardafui and runs at first towards the south-east to near the Chagos Archipelago, where it bends at first south and then west of south and, so far as the few soundings indicate, is continued as far as the island of Rodriguez. At this point the ridge loses its great height but, in all probability, is con-

tinued on at a lower level to constitute a Mid-Indian Ridge, that appears closely to resemble the corresponding ridge down the middle of the Atlantic Ocean; further to the south this ridge expands into a wide plateau from which the islands of New Amsterdam and St. Paul rise from one base and the islands of Kerguelen, Heard and Macdonald from a second, to which the name Kerguelen-Gaussberg Ridge has been given; finally the ridge blends with the Antarctic continent. At its north-western extremity there is some indication that the Carlsberg Ridge is continued towards the north-east to join a ridge that has recently been discovered by the John Murray Expedition and to which the name Murray Ridge has been given; this second ridge is also double in character, enclosing a deep gulley along which the depth is some 3,660 metres while the banks on either side are covered by water of a depth of only 550–730 metres, and passing in a north-easterly direction across the entrance to the Gulf of Oman it joins the coast of India a little to the north of Karachi and seems to be a submarine continuation of the Kirthar Range of Sind. Running from east to west along the coast of Baluchistan and Iran a third interrupted mountain chain has been discovered beneath the sea; this seems to form a part of the Zagros mountain system. To the south-west of the Carlsberg Ridge and running more or less concentrically with it lies the curved ridge of the Seychelles-Mauritius or Mascarene Bank, at the northern end of which lies the Seychelles Group of islands and at the southern end the islands of Réunion and Mauritius; along the line of the bank is a series of reefs, namely Fortune, Saya de Malha and Nazareth Banks, together with Albatross Island and Cargados Carajos Reef. From the region of Saya de Malha Bank a somewhat lower submarine ridge arises on the north-east side and curves westward to merge finally with the East African coast. It is thus clear that the Indian Ocean is divided from north to south by a great mountain range into eastern and western sections, while subsidiary ridges further subdivide each area into smaller basins.

Geology of the sea floor

At the present time we know extremely little regarding the nature of the rocks of the sea-bottom. The abrupt cessation of the Deccan Trap along the west coast of India clearly indicates that this basaltic outflow must have extended far to the west of the present coast line; it was therefore of special interest to obtain samples of rock of a basaltic character both from the Carlsberg Ridge itself, in Lat. 1° 25′ 54″ N.; Long. 66° 36′ 12″ E. from a depth of some 3,385 metres and again from the deeper area of the Arabian basin, in Lat. 6° 55′ 18″ N.; Long. 67° 11′ 18″ E., from a depth of about 4,850 metres. A careful examination of the chemical and physical characters of these fragments showed, however, that they differ from the Deccan Trap, and indeed from all known sub-aerial basalts, in having considerably less iron in their composition and also in being much less radioactive. Hence they cannot be regarded as a

submarine continuation of the Deccan outflow. It seems probable that the Carlsberg Ridge and its continuation, the Mid-Indian Ridge, are of volcanic origin throughout their whole length, for where the ridge reaches the surface, as at Rodriguez or the islands at the southern end, the rock is in every case volcanic. The same origin accounts for part at least of the Seychelles-Mauritius Bank for, although the Seychelles at the northern end are largely composed of granite, there is some basalt as well and the southern islands of Mauritius and Réunion are definitely volcanic in origin. So also is the basis on which Providence Reef is situated.

Unfortunately we have as yet no conclusive evidence of the age of this great mountain system ; but the age of Providence Reef has been shown to be Tertiary, while the islands at the southern end of the Mid-Indian Ridge, namely Kerguelen, New Amsterdam, St. Paul, Heard and Macdonald, are also all of Tertiary age. If, as seems possible, the Murray Ridge is a continuation of the Kirthar Range of Sind, then this too is of Tertiary age. In this connection it is interesting to note that the line of the Murray and Carlsberg Ridges together forms an exact counterpart of the line taken by the great Rift Valley system of Africa, the two forming a looking-glass reflection of each other on either side of the meridian 55° E. ; both systems, the Rift Valley and the Carlsberg Ridge, are, further, areas of earthquake intensity, a linear belt of secondary intensity passing along each ; such a similarity suggests that the two systems are part of one orographic movement and, if this be so, then there is no doubt that the northern extension of the great Mid-Indian Ridge must be of Tertiary age.

Geologists have reached the conclusion that the long straight line of the west coast of India is the result of an extensive scarp-faulting that occurred at some period after the outflow of the Deccan Trap, for only so can the abrupt cessation of this deposit, which reaches a thickness of some 9,000 feet on the Bombay coast, be accounted for ; the age of the Trap is generally stated to be about the close of the Cretaceous, though it may have continued on into the Eocene, and the west coast of India is supposed to have assumed its present form probably in the Pleistocene period. Blanford has further suggested that a similar fault is to be found running from east to west along the coast of Makran and Baluchistan, and the presence of a submerged part of the Zagros Mountain system seems to corroborate this. The whole of the south-eastern coast of Arabia, from Ras Fartak eastwards past the Kuria Muria Islands almost as far as Ras al Hadd, for the most part terminates in steep or nearly vertical cliffs of stratified sandstone and limestone that may reach a height of 400–600 feet and that clearly, from the horizontal position of the strata, must have been deposited under water ; here the continental shelf is narrow and drops very irregularly into deep water. As the sandstone must originally have extended very considerably further towards the south or south-east, it seems highly

probable that the straight line of the Arabian East African coast is, like that of India, due to an extensive scarp-faulting. If these views be correct, then the whole of the northern part of the Arabian Sea is surrounded by a system of faults and, in conjunction with this there is, at the least, an apparent continuity of the land and submarine mountain ranges; the deep gulley of the Murray Ridge system may perhaps be itself a line of faulting or alternatively may be the now drowned continuation of the old tertiary bed of the Indus River or of its hypothetical precursor the Siwalik or Indo-Brahm River of Pascoe and Pilgrim. All this strongly suggests that at one time, possibly in the Miocene Era, a large area of land occupied this corner of the Indian Ocean but that this has subsequently been fractured off and has subsided to the level of the sea bottom, some 3,300 metres below the surface. The age of the deposits along this stretch of the coast that have been broken across range from Oligocene to early Pleistocene, so that it seems probable that this subsidence, if it be a fact, also occurred in the late Pleistocene Epoch and was thus contemporaneous with the faulting down the west coast of India. In most places along the continental margin the submarine rocks are covered with a thick deposit of terrigenous mud and it is but rarely that actual rock masses are brought up in the trawl or dredge. Up to the present time no specimens have been obtained along the west coast of India, but in the Gulf of Oman several rock fragments were obtained off Muscat from a depth of 274 metres in Lat. 23° 41′ 48″ N.; Long. 58° 36′ E., and these seem to agree in their general character with the rock of the mainland. Off the Kuria Muria Islands between ½ and 1 ton of angular fragments of granite were taken in the dredge from 1,415 metres depth and these seem to have formed part of a scree slope, that is in all probability a submarine continuation of the granite scree slope of the western end of the island Jezirat Hallaniya and the adjoining Soda Island. Fragments of a very similar granite were also obtained from a reef on the continental shelf to the east of Ras Madraka (Lat. 19° 22′ 36″ N.; Long. 59° 52′ E.). Thus along this stretch of coast, where we have reason to believe there is a great scarp fault, the submarine rocks appear to agree with those of the land, as of course they should if such a view is correct.

Changes of sea level

Up to a few years ago practically all changes in the relative levels of sea and land were attributed to movements of the latter, but within recent years it has become recognized that sea-level is by no means a fixed plane and that there have been in the past wide oscillations and movements during which the sea-level has fallen and risen again. From the Oceanographic point of view perhaps the most important movement was that which, according to the view put forward by Daly and others, occurred during the last Glacial Period. At this time the sea-level became markedly

lowered, partly by the actual abstraction from the ocean of large quantities of water, that were locked up in the Polar regions in the form of ice, and partly by the mass attraction of these large ice masses that drew a further quantity of water away from the tropical regions towards the poles. The sum of these two factors caused a fall in sea-level throughout the tropical belt that Daly conservatively estimated at some 60–70 metres, but recently another American, Shepard, in order to account for the presence of deep submarine gulleys off the mouths of many of the great rivers in all continents, has put this fall at as much as 915 metres, his argument being that these submarine gulleys are a part of the old river bed and must have been cut by the rivers when the sea-level was at a correspondingly lower plane.

Submarine gulleys

At least two such submarine gulleys are found round the coasts of India. On the west side, opposite the present mouths of the Indus river, lies the Indus 'Swatch' that cuts through the edge of continental shelf, commencing at a depth of about 30 metres and at its mouth reaching a depth of about 1,134 metres, on each side of which the walls of the gulley rise up to a depth of only 200 metres. At the head of the Bay of Bengal a similar deep gulley, known as the 'Swatch of no ground', lies off the mouths of the Ganges; here too the gulley commences at a depth of about 30 metres and cuts through the edge of the continental shelf, having a depth of about 1,100 metres at its mouth. There is some evidence that yet a third submarine gulley exists off the mouths of the Irrawaddi river in the Andaman Sea. The theory that these submarine gulleys are submerged river-beds rests on the assumption that the continental shelf is an original part of the continent, a view that is by no means universally accepted. An alternative view holds that they are due to the deposition of mud and silt, brought down by the rivers, along the two sides of the outflowing river water, the deposition along the line of the flow being prevented by the corresponding inflowing current of sea-water below the river outflow. The natural course of such an outflowing surface-current of fresh water must depend very largely on the direction of the prevailing wind and in the Indian region this, during the north-east monsoon, is, as the name implies, from that point of the compass, and it is interesting and suggestive to note that in each case this is the direction taken by the submarine gulley, which runs from NE. towards the SW.

Coral reefs

During the Glacial Period, when the sea-level was certainly lower than it is to-day, many banks and islands must have been eroded and cut down by wave action or by sub-aerial erosion. With the subsequent return of a warmer climate and the consequent melting of the great ice caps, the sea-level once again rose and submerged these banks: simultaneously the temperature of the sea became warmer, so

that corals, particularly reef-forming corals, and the calcareous Algæ, Coralinaceæ, etc. were again able to flourish and the eroded banks formed a suitable base on which they could settle and build up reefs and atolls, the height of the reef keeping pace with the steady rise in the water-level. Certain areas seem to have been particularly favourable for such development and in the Laccadive, Maldive and Chagos Archipelagoes were formed extensive reefs, many of which show a typical atoll formation.

In other regions, such as around Southern India and Ceylon, along the coast of Southern Burma, including the Mergui Archipelago, and on round Socotra, Java and the islands of the Malay Archipelago to Australia, we find extensive fringing reefs; similarly along part of the East African coast and up the length of the Red Sea there is extensive reef formation. Around the Andaman and Nicobar islands in the eastern part of the Indian Ocean and fringing Zanzibar and Pemba islands, the Seychelles, Madagascar, Mauritius, Réunion and other islands in the western part are other reefs; while crowning suitable bases we find numerous isolated reefs such as Cargados Carajos, Fortune, Saya de Malha and Nazareth Banks, together with a few isolated atolls such as Farquharson and Aldabra in the west and Cocos-Keeling in the east. Coral growth is thus clearly widespread throughout the Indian Ocean but there are certain regions in which it is conspicuous by its absence. In certain regions, such as around the Bay of Bengal, the reason for this appears to be the adverse effect of the mud and silt that is carried down by the great rivers and is poured into the sea along the continental shelf, smothering and killing off any coral organism that may have found its way there; but in the region of the East African coast to the south of Cape Guardafui and along the south-east Arabian coast such an explanation cannot hold good and it seems probable that in these latter areas the absence of coral is to be attributed to a seasonal upwelling of deep and cold water brought about by the wind of the south-west monsoon.

The fall of sea-level in the last Glacial Period seems to have had a particularly marked effect on the region of the Malay Archipelago. Prior to this epoch a large area of dry land extended to the south-east and included what are now the islands of Sumatra, Java and Borneo, all of which were connected together and formed a part of the Asiatic continent. A little further to the south-east a second large area of land extended northwards from the Australian continent and connected Australia with the island of New Guinea. During the lowering of the sea-level, much of these two areas became eroded and peneplaned, and when at the close of the epoch the sea-level again rose this peneplaned area became drowned, thus causing the separation of the various islands and giving rise to the extensive shelf areas that exist at the present day. This drowning

of the Malayan area must have very greatly increased the connection between the Indian and Pacific Oceans.

Still later and probably not more than some 4,000 years ago a second, though smaller, fall of sea-level occurred throughout the tropical belt of all the great oceans, possibly as a result of an accumulation of ice in the Antarctic continent. On this occasion the sea-level fell by only about 7 metres and the result can be seen clearly around the continental coasts in the form of 'raised' sea beaches and wave-worn 'benches' in the cliffs; but the most important result of this fall from the point of view of the Oceanographer was the effect that it had on the coral reefs. Coral can only grow up to sea-level and the fall of this level brought the topmost parts of the reefs above water and thus gave rise to the islands, composed of coral rock, that are to be found at the present day dotted over the reefs or around the rim of the lagoons. In each atoll there was originally, in all probability, a nearly continuous rim of 'land', only interrupted in places by the deep channels that ran from the open sea through the reef into the lagoon; but during the subsequent years wave-erosion and sub-aerial weathering have destroyed much of the rim, and at the present day only a few islands remain, situated usually on the least exposed parts of the reefs, and these too appear to be undergoing gradual destruction, so that after a few more centuries the reefs will in all probability have been completely eroded down to sea-level again and there will then be no islands to mark the position of the coral reefs.

Bottom Deposits.

At the present time we still know practically nothing of the character of the rocks that form the floor of the Indian Ocean. Overlying these rocks are the muds and oozes that have been gradually deposited ever since the ocean first came into existence. These deposits are derived from several sources, namely :—

(i) Water-borne detritus and mud brought down by rivers and poured into the ocean—the result of land-erosion;

(ii) The products of marine erosion on the coasts and the breaking up by wave action of the continental margin, as well as the remains of animal and plant organisms, such as shells, corals, calcareous algæ (*Halimeda*), etc., thus giving rise to marine muds;

(iii) Volcanic lava and ash thrown up by submarine volcanoes.

(iv) Air-borne dust and cosmic particles of extra-terrestrial origin; and lastly

(v) The remains of pelagic and other marine organisms, such as Diatoms, Foraminifera, Radiolaria, Pteropoda, etc., which build up from the chemical constituents

of the water, shells or skeletons that, when the animal dies, sink to the bottom and form a varying proportion of the mud or ooze.

It is the varying proportion of these constituents that give to the deposit its characteristic appearance and composition; thus round the coasts and forming at least a large part of the Continental shelf we find terrigenous muds; but, as we pass away from land into greater depths of water, the remains of pelagic organisms, especially those of animals that have a calcareous shell, begin to preponderate and in these regions the sea-floor is usually covered with Globigerina ooze, or where the shells of the pelagic molluscs, the Pteropoda, predominate, with Pteropod ooze. In still greater depths the action of the sea-water dissolves these calcareous remains before they are able to reach the bottom, but the siliceous remains of other pelagic organisms are unaffected and we thus get a type of deposit in which the skeletons of pelagic Radiolaria predominate, and to this type the name Radiolarian ooze has been given, or else, as for instance around the South Polar region, the characteristic feature of the deposit is the remains of Diatoms, and hence here we get a Diatom ooze. Finally, where Foraminifera, Radiolaria or Diatomacea form but a small part of the deposit and the main bulk is derived from air-borne dust and cosmic particles or perhaps from volcanic debris or very fine terrigenous mud, we get the type of deposit that is termed Red Clay.

Terrigenous mud

Associated with the presence of numerous rivers opening into the Bay of Bengal and Andaman Sea we find, as one would expect, that much of the sea-floor is covered with terrigenous muds, and as a result of this continual deposition it has been estimated that the sea-ward edge of the Continental shelf at the head of the Bay is steadily moving southwards at a rate of one mile in forty years. As we approach the mouth of the Bay this mud gives place to Globigerina ooze with which in the central area is mixed a number of masses of water-logged pumice, that in all probability was largely derived from the great explosion of Krakatoa in 1883 and after drifting up into the Bay became water-logged and sank, being slowly swept by the rotatory movement of the deep water in the Bay inwards towards the centre of the region.

Similarly at the head of the Arabian Sea, where the out-flowing water from the Persian Gulf sweeps along the detritus from the Tigris and Euphrates rivers, and off the coast of India where the Indus and Narbadda rivers pour their silt-laden waters, the sea-floor is covered with a green terrigenous mud, that in the deeper levels of the Gulf of Oman gradually changes to a grey mud or clay. Under the influence of the north-east winds a great deal of this mud seems to be swept by the current along the coast of Arabia and even into the Gulf of Aden.

Pteropod ooze

In the Red Sea the bottom deposit is of a different type in the northern and southern areas; in the northern part the deposit is a yellow mud, whereas in the southern region the colour changes to brown and here the inflowing current from the Gulf of Aden carries in large numbers of Pteropoda, which are killed off in thousands by the sudden change in the character of the water, and their shells, falling to the bottom, give rise to a Pteropod ooze, in which a calcareous rock appears to be in process of formation. Patches of Pteropod ooze are also to be found in the Andaman Sea and on the floor of the 'Swatch of no ground' off the delta of the Ganges.

Azoic area

Along the eastern part of the South Arabian coast and in the Gulf of Oman a large area of the sea-bottom appears to be markedly inimical to animal life for between the depths of approximately 200 and 1,250 metres the whole of the region comprises a large azoic area and this condition reaches its height off Ras al Hadd where the bottom mud is strongly impregnated with Sulphuretted Hydrogen gas, the source of which is at present unknown. Small quantities of the same gas are to be found in the muds of some of the Maldive Atolls and in a few other localities, as off Bombay and off the Arabian coast near Aden.

Globigerina ooze

In the deeper waters of the Indian Ocean the bottom deposit changes from terrigenous mud, or in the neighbourhood of the great coral reefs from coral mud, to Globigerina ooze.

Red Clay

In the deepest areas of all and especially in the Arabian Basin to the north-east of the Carlsberg Ridge, the Indo-Australian Basin in the south-east part of the ocean between the Mid-Indian Ridge on the west and the Malay arc and Australia on the east, and in the South-Australian Basin the floor is covered with Red Clay, and a patch of this deposit is also found in the Madagascar Basin.

There is very little Radiolarian ooze in the Indian Ocean but patches of this deposit have been found in the Indo-Australian Basin to the north of Cocos-Keeling Atoll, in the South Somali Basin, where it seems to be surrounded by a small patch of Red Clay, and in the Mascarene Basin.

Diatom ooze

In the southern area, from about Lat. 45°–50° S., the bottom deposit consists of Diatom ooze, a type of deposit that is characteristic of Polar regions and is associated with the great prevalence of Diatoms in the sea-water of these high latitudes; it is extremely interesting to note how closely the northern limit of this deposit coincides with the line of the Sub-polar convergence, where the cold polar water meets and is driven below the water of the West-wind Drift.

HYDROGRAPHY. (Figure 2).

The Indian Ocean is filled with water that can be divided, as we pass from the surface to the bottom, into a succession of strata, each characterized by the temperature and salinity of the water, as well as by the amount of oxygen that is dissolved in it. Each stratum is in a state of continual movement, the direction of flow being determined by external forces, such as the winds and the spin of the earth, and by an internal factor, the density. Recent work has indicated that there are at least four and possibly five such strata.

Surface stratum

At the surface and extending downwards for some 100 metres is a stratum of water that is continually moving from place to place under the combined influence of the wind and the spin of the earth, while its composition varies from area to area and from season to season according to the degree of evaporation, that raises the salinity, or the amount of rainfall, that lowers the salinity either directly by oceanic storms or indirectly by the outflow of river water and in Polar regions by the amount of melting of the ice. The extent to which rainfall will influence the salinity of the sea-water varies again from region to region, according to the number and size of the rivers that empty into it. Such a lowering of salinity is very marked on the east side of India, since opening into the Bay of Bengal there are no less than six large rivers, namely, the Cauvery, Kistna, Godavery, Mahanaddi, Ganges and Brahmaputra, as well as innumerable smaller streams, while further east and opening into the Andaman Sea are the Irrawaddi, Sittang, Salween and Tenasserim rivers. On the west side of India the only rivers worthy of note that flow directly into the Arabian Sea are the Indus, Narbadda and Tapti. As a result the surface water of the Bay of Bengal has a lower salinity than that of the Arabian Sea and this is particularly the case during the months that follow the rainy season of the south-west monsoon.

Surface currents

In the Tropical and Sub-tropical region of the Indian Ocean the surface water is driven along by the south-east trade winds in the southern hemisphere and by the alternating north-east and south-west monsoon winds in the northern hemisphere, so that during the winter months the bulk of the surface water tends to converge on the African coast. In the neighbourhood of the north end of Madagascar the westerly-flowing current divides into two streams, one of which turns north to form the Somali stream, that is very weak at this time of the year but which forms a very strong current during the south-west monsoon, while the other bends to the south and, passing between Africa and Madagascar, is reinforced by a further part of the south-equatorial current that sweeps round the southern end of Madagascar. These two masses of water

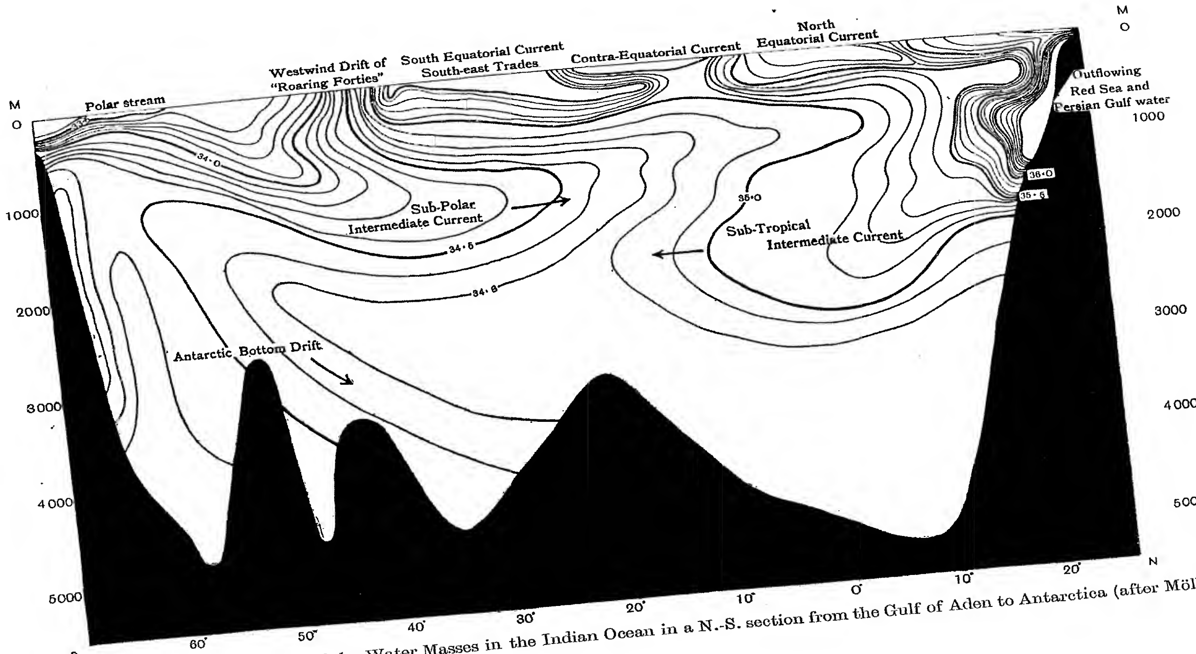
combine to form the great Agulhas current, part of which flows round the Cape of Good Hope into the Atlantic and joins the Benguela current and the south-east Trades of that ocean and the rest swings to the south-east and meets with and joins the West-wind Drift of the 'Roaring Forties'. During the north-east monsoon there is a strong flow of water from the Pacific to the Indian Ocean through the Straits of Malacca into the Andaman Sea and out into the Bay of Bengal, and this, joining with the low salinity Bay of Bengal water, can be traced flowing westwards as far as the Seychelles; during the south-west monsoon this flow from the Pacific to the Indian Ocean is stopped or may be reversed, but there is now a strong flow of water westward between the Malay Archipelago and Australia. In the Equatorial region between Lats. 5° and 10° S. there is a reverse flow of water from west to east, constituting the Contra-equatorial current, that on meeting the less saline surface water of the Bay of Bengal sinks beneath it to join one of the deeper strata.

Tropical Intermediate current

To the west of India the Red Sea opens through the Gulf of Aden into the Arabian Sea on its north-west and the Persian Gulf through the Gulf of Oman on its north side; both of these areas are regions of very little rainfall and high evaporation, and, although the Tigris and Euphrates rivers open into the Persian Gulf, the high evaporation more than counterbalances the influx of river water, so that the outflowing water from these areas has a high salinity and high temperature. As this water flows seaward it becomes cooler and, as a result of the consequent increase in density, sinks below the surface and forms one of the deeper water strata; this stratum is known as the Tropical Intermediate current, and as it passes southwards is in all probability joined opposite the southern end of India and Ceylon by a mass of water that has sunk down beneath the surface in the Bay of Bengal and that on leaving the Bay seems to swing towards the west or south-west. This combined mass of water passes across the Equator at a depth of about 1,000 metres and appears to swing towards the south-east, sinking as it goes, so that in Lats. 40°–50° S. it lies at between 2,000 and 3,000 metres depth; further south than this it tends to rise again towards the surface.

Sub-polar Intermediate current

In the southern area of the Indian Ocean under the influence of the west winds of the 'Roaring Forties' there is set up a circum-polar movement of the surface-water that is continually moving towards the east and north-east; the line along which this sub-polar water meets the water of the South-east Trade Drift is known as the Sub-tropical Convergence line and here the sub-polar water sinks beneath the surface and can be traced flowing towards the north at a depth of about 1,000 metres as far as the Equator or even beyond, for ultimately some of this Sub-polar Intermediate current,



TEXT-FIG. 2.—The Circulation of the Water Masses in the Indian Ocean in a N.-S. section from the Gulf of Aden to Antarctica (after Möller).

as it is termed, can be traced as far as the Gulf of Aden and the Gulf of Oman. To the south of the 'Roaring Forties' and between this and the Antarctic continent the surface Polar water is continually moving towards the north-east; owing to its greater density this water is driven below the Sub-polar water, forming the Sub-polar convergence or 'Meinardius Line.'

Antarctic Bottom Drift

Finally in the deepest levels of all we find a mass of water of low salinity and low temperature that is coming from the South Polar region and is moving, along the bottom at first towards the north-east and then to the north, up into the Indian Ocean and on past the Equator into the Arabian Sea and the Bay of Bengal, forming what is known as the Antarctic Bottom Drift. Owing to its situation on the bottom this deep layer is particularly influenced by the bottom topography; submarine mountain chains or the trend of the continental coast-lines will largely determine the direction of flow and we thus find that the Mid-Indian Ridge splits this Drift into two great streams; the one to the west of the Ridge passes northwards till it comes in contact with the Mauritius-Seychelles bank, which splits it into two streams that pass respectively to the east and west of this curved mountain chain into the North and South Somali Basins. The western stream flows towards the north-west, probably turned in this direction by the curve of the Mauritius-Seychelles bank, till it meets the African coast, where it is deflected towards the north-east and, finally, passing Cape Guardafui and Socotra flows in part into the Gulf of Aden, while the last traces of it run parallel to the Arabian coast and so enter the Gulf of Oman. The eastern branch appears to be in the main deflected upwards towards the surface, where it may serve to augment the mass of water that is flowing eastwards in the Contra-equatorial current. East of the Mid-Indian Ridge between the Kerguelen Plateau and Australia the second great stream of Antarctic Bottom Water flows north-eastwards and meeting the curve of the Malayan arc swings northwards to the entrance of the Bay of Bengal, where, meeting Carpenter's Ridge, it too is split into two streams, one passing on into the Bay along its east side and the other sweeping westward across the mouth of the Bay till it reaches the east side of Ceylon and South India and is again split into two streams, one branch passing up the east side of India into the Bay of Bengal and the other passing further westwards into the Laccadive Sea and possibly across the Maldive Ridge into the Arabian Basin. As a result of the two streams passing into the Bay of Bengal along its two sides, a complicated rotary movement of the water masses is set up on the bottom and this has resulted in floating objects such as pieces of pumice, that gradually become water-logged and sink, being slowly swept round and round till they finally come to rest on the bottom in the central region of the Bay.

In addition to these movements of water within the Indian Ocean there is evidence to show that a continual exchange of deep water is going on between the Indian and both the adjacent oceans, the Atlantic and Pacific. On the south-west side of the Indian Ocean at a depth of about 2,000–4,000 metres there seems to be a deep current of water, having a low salinity but a high oxygen content, coming out of the Atlantic Ocean and flowing eastward past the Cape of Good Hope into the Indian Ocean and then northwards up the east coast of Africa as far as Madagascar. A similar deep current probably passes to the south of Australia between the Indian and Pacific Oceans.

Seiches

In addition to these currents and drifts in the deep waters of the Indian Ocean there is some evidence that seems to indicate that the deep water is, at least in certain seasons of the year, undergoing a periodic to-and-fro swing or 'seiche' in some of the more or less enclosed areas. Up to the present time such evidence is available only for the Bay of Bengal and the Andaman Sea; and it is especially in these two regions that the inflowing river water causes, as we have seen, a lowering of the salinity of the surface stratum, so that a layer of less saline water rests on a deeper more saline stratum. During each monsoon the surface stratum under the influence of a more or less constant wind, blowing from the north-east or south-west according to the season, is driven towards one side of the region and is there piled up against the coast line so that this surface layer becomes thicker on that side of the area than on the other and the plane of demarcation between the two layers becomes inclined; with the cessation of the impelling wind at the close of each monsoon this plane of demarcation immediately tends to return to the horizontal and in consequence there is developed in the bottom stratum a swing of the water that has a time period depending on the depth and density of the two strata and the size and shape of the containing basin. As a result of this to-and-fro swing the deeper stratum will periodically and alternately at each end of the basin be brought nearer to the surface and at such times under the influence of wave-action there will result a certain degree of mixing between the upper and lower strata, so that the salinity of the coastal water will exhibit a rise and fall showing the same periodicity. No actual proof of such a swinging movement in the deeper water has as yet been obtained in these two regions but it has been found that the surface salinity of the coastal waters of both the Bay of Bengal and the Andaman Sea exhibit a rhythmic rise and fall, the period of which corresponds exactly with the time that a seiche should take in these waters, namely, in the Andaman Sea, where the seiche would appear to be of the uni-nodal type if it be present, from 17–19 days and in the Bay of Bengal, where the seiche would seem to belong to the bi-nodal type, of 15·5 days in the long axis of the Bay and of some 5·5—6 days in the transverse axis.

Associated with this periodic variation in the salinity of the surface water there may be at certain seasons an equally periodic appearance in the upper levels of large numbers of animals, such as small Salps, Rhizostomous Medusæ or certain species of pelagic Crustacea, that, in all probability, normally inhabit a deeper stratum but are carried up towards the surface by the upward swing of the deeper water.

Oxygen content

From the point of view of the marine Biologist one of the most important ingredients of the sea-water is the oxygen that is contained in solution. This oxygen is derived from the surface, partly by direct solution from the atmosphere in the uppermost water layer and partly by the action of the chlorophyl-bearing phyto-plankton, that under the influence of direct sunlight carries out the process of photo-synthesis, building up certain simple chemicals, such as nitrates and phosphates, into their body tissues and setting free oxygen that is at once dissolved in the water ; clearly this process can only be carried out in the extreme upper levels, since the depth to which light can penetrate the sea-water is very limited and, where there is a large amount of plankton in suspension, this depth will be even smaller than usual. Correlated with this we find that whereas there is a fair supply of oxygen in the upper levels, this rapidly diminishes as we pass downwards, the oxygen being used up by the zooplankton and other pelagic animals, till at a depth of about 100 metres there is usually less than 1·0 cc. of oxygen in a litre of water and at 800–1,000 metres depth less than 0·1 cc. Passing still further downwards towards the bottom we find that the amount of dissolved oxygen again begins to increase till in the deepest depths the amount present may be as much as 2·5–2·75 cc. per litre ; this increase in the bottom levels is correlated with the sinking of the South Polar water from the surface to give rise to the Antarctic Bottom Drift, that carries a supply of oxygen along the bottom of the ocean up to and beyond the Equator.

Nutrient salts

As the nitrates and phosphates in the surface waters are built up into the tissues of the plants and subsequently, after digestion, into the bodies of the animals that feed on the plants, the supply of these salts at the surface will gradually be depleted, whereas, as the animals and plants die and their carcases sink to the bottom, where by bacterial or some similar action the nitrates and phosphates are again set free, the bottom water will gradually become more and more rich in these salts. The replenishment of the surface and upper levels can thus only be brought about by an upwelling of bottom water towards the surface. Such upwelling is known to occur along the east coast of Africa near Cape Guardafui and along the south-east coast of Arabia during the south-west monsoon, for the study of hydrodynamics has shown that under the influence of a strong wind the water of the sea-surface is swept in the northern hemisphere,

not in the direction in which the wind is blowing but at an angle to the right of this, so that the south-west monsoon wind, which blows more or less parallel to these coasts, will drive the water away from the land and thus cause deep water to well up to the surface to take its place; a similar upwelling of water appears to take place on the east of the Seychelles-Mauritius bank, where it serves to augment and to replenish the supply of nutrient salts of the Contra-equatorial current. In consequence of this replenishment of the nutrient salts in these two areas we find that the amount of plankton present in the upper levels is particularly rich. In addition to this supply of nitrates from the bottom water a further source of supply is in all probability to be found in the Tropics in the rainfall, and especially that which occurs during thunderstorms. During such storms the electrical discharge in the lightning causes the formation of nitric acid and this is carried down in the rain; it has been estimated that as much as 5 tons of this acid is formed annually over every square mile of India. Much of this acid becomes combined with alkalies in the soil and thus serves to fertilize the land but, in addition to the amount that falls directly into the sea, a great deal must also be carried into the great rivers and eventually be poured into the sea, especially in the Bay of Bengal and the Andaman Sea, into which so many of the rivers of India and Burma open; during the north-east monsoon the water is swept out of the Bay of Bengal and round the south of Ceylon westwards and can be traced extending on the surface in a wide belt as far as the Seychelles, and during the John Murray Expedition the surface water in the neighbourhood of the Maldive Archipelago in February was found to be particularly rich in nitrates, that may thus be accounted for.

Mineral salts

Along with the supply of nutrient salts the large rivers carry down a supply of mineral salts that are beneficial to the growth of Diatoms and it has been found that estuarine regions are particularly rich in phyto-plankton, whereas, as we proceed further and further towards the open ocean, the character of the plankton changes and becomes zoo-planktonic in character. Usually in the open waters of the tropical ocean the amount of zoo-plankton present at any given time is comparatively small, as compared with that in more northern or southern regions; this has been used as an argument in support of the view that tropical waters are relatively deficient in animal life as compared with the cooler, more northerly or southerly regions; but it must be borne in mind that the rate of reproduction in the Tropics is considerably more rapid than in colder climates and moreover in all probability the breeding season is much more prolonged, so that there is not so great a degree of disparity, if indeed there be any, in the total amount of life in the ocean between Tropical and Subtropical or Polar regions.

In spite of the fact that plankton of the zoo- and phyto-types appears to have, at any rate in certain areas, a mutually exclusive action on one another, so that where phyto-plankton is particularly abundant the number of animals present is comparatively small, there is no doubt that the amount of zoo-plankton than can exist in any area of water depends on the amount of phyto-plankton on which the animals can feed, whereas on the other hand an increase in the number of herbivorous animals will cause a fall in the amount of plant life. It has been found in Indian waters, as in the more northerly waters of the North Atlantic, that there is annually an increase in the amount of phyto-plankton present in the surface waters in the month of April—the spring outburst—at the time of year when in Indian waters the sea-water is warmest and when there is plenty of sunlight. A month or two later, however, this burst of plant life is succeeded by a marked increase in the amount of the zoo-plankton and simultaneously the quantity of the phyto-plankton becomes reduced.

Biology.

Since the vast majority of marine animals at some stage or other of their existence pass through a floating or pelagic stage, during which they form a part of the plankton that is swept along by the currents and so drifts from place to place in the ocean, a study of the movements of the water masses is of the greatest importance for the right understanding of their distribution, not only because this movement provides the necessary mechanical propulsion but because within the limits of such currents the water maintains, with only very slight and gradual changes, a more or less constant physico-chemical condition that is required by the organisms inhabiting it, any rapid change of either salinity or temperature being almost invariably fatal.

Many of the planktonic animals are capable of a certain degree of independent movement by which they are able to adjust their level in the ocean ; thus certain organisms may be found at or near the surface at night, but at the approach of dawn and the onset of brilliant light, which they almost universally dislike, they swim downwards through a comparatively short distance and so reach a level where the intensity of the light is best suited to their existence ; as the day closes they once again move upwards and make their appearance on the surface. Such a vertical migration may be assisted by the daily change-over of the upper water levels, that is brought about by the daily change in salinity. During the day the uppermost stratum of the water becomes, as a result of evaporation, more saline, though owing to warming by the sun's rays it is rendered less dense and so remains at the surface ; with the onset of night and consequent cooling this surface water becomes more dense and sinks to a deeper level, being replaced at the surface by

water which wells up from below and this daily 'change-over' in the upper stratum must to some extent carry the plankton with it, so that an organism that swims downwards to a deeper level during the early part of the day may again be swept towards the surface at night. Such a vertical migration will, however, have but little effect on the horizontal movement and thus the distribution of the plankton over such a wide area as the Indian Ocean must in the main depend on the strength and direction of the various currents at all depths and thus these will to a large extent influence and determine the general character of the fauna in any given region.

As we have seen, there is, owing to the general trend of the surface currents and especially during the north-east monsoon, a transference of large masses of water from the Pacific Ocean through the Malay Archipelago to the Indian Ocean; on the other side, however, but little of the surface water of the Indian Ocean passes westward round the Cape of Good Hope into the Atlantic Ocean, and that which does so comes into contact and becomes intimately mixed with a cold current, the Benguela current, that is derived partly from the Sub-polar region and partly by upwelling from below off the south-west coast of Africa. The consequent fall of temperature in the surface water would be extremely harmful to any pelagic organisms that might have been swept round from the Tropical or Sub-tropical regions of the Indian Ocean and few would manage to survive it. Thus, while there is a close connection faunistically between the upper levels of the Indian and Pacific Oceans—the two together forming a vast Indo-Pacific region—, the Atlantic Ocean has developed a fauna that is more or less characteristic of that area; but even so, a number of littoral weed-haunting forms, such as the Harpacticid Copepoda, appear to have been able to make their way westward, and, following the currents of the Atlantic, have reached the east coast of North America, for no less than 30% of the known Indian Harpacticids have been found on the shores of Wood's Hole, Massachusetts and around Bermuda, while, continuing along the North Atlantic Drift and the Gulf Stream, some 16% have reached the coasts of England and about 12% have got as far as Norway.

Within recent years the cutting of the Suez Canal has provided a short cut for organisms to pass from the Indian region through the Red Sea and the canal into the Mediterranean Sea, and already a certain number of animals have made their way from east to west; doubtless with the passing of the years more and more will be able to do so, so that the fauna of the Mediterranean, and especially its eastern basin, may in time to come have a close affinity with that of the Indian Ocean, the extent of the change depending on the degree to which Indian forms can supplant those now living in the Mediterranean.

On the eastern side of the Indian Ocean the free passage of surface water between the Pacific and Indian Oceans has resulted

in the fauna of the Malay Archipelago being at the present time decidedly Pacific in type; but in the not far distant past there seems to have been a very rich production of new species in the Malayan region and the movement of the water masses has caused the extension westward of this fauna. A large number of these Pacific or Malayan species have been carried or have actively migrated westwards; many have invaded the Andaman Sea and appear to have been unable to get any further, but numerous others have been able to reach and have established themselves in the great coral-bearing regions of the Chagos, Maldive and Laccadive Archipelagoes, in the Seychelles and around Réunion and Mauritius, and even ultimately have reached the African coast and the Gulf of Aden. In some at least of the various groups of animals it has been found that the further west we proceed, the fewer are the number of Malayan species to be found and, even in those instances where a species has been able to survive and establish itself, the individuals are often smaller and are 'depauperized' as compared with their congeners in the Malayan region. In other cases the change from east to west seems to have been accompanied by a structural change in the organism and in consequence we find that a number of species are peculiar to the Indian region but that their nearest relatives, and those from which they have in all probability been evolved, are to be found in the Malayan Archipelago.

It has recently been discovered that a very high percentage of species of Marine Algæ are common to the Indian Ocean and the North Atlantic Ocean, some even occurring in the Arctic region. The presence of North European species in the Arabian Sea is attributed to a migration from the north-west when an open connection between the two regions existed through the Tethys Sea; similarly Indo-Pacific species are supposed to have migrated through this sea from the Tropics to the Mediterranean. Similarly, as regards the fauna numerous authors in the past have drawn attention to the large percentage of littoral-haunting species and especially of species from depths ranging from 350 to 1,900 metres that are common to the Indian Ocean and the North Atlantic. Alcock in his report on the Deep-Sea Fishes states that 'if we estimate the number of Indian genera of marine fishes at 350 and of species at 1,200, then over 56 per cent. of the genera and close on 5 per cent. of the species are also found in the Atlantic-Mediterranean region.' The explanation of this degree of similarity is again attributed to the former presence of a direct connection between these two regions through the Tethys Sea. It must, however, be borne in mind that the constant influx of water at some 2,000–3,000 metres depth from the Atlantic Ocean past the Cape of Good Hope into the Indian Ocean, as well as the steady drift of Antarctic polar water, in either the Sub-polar Intermediate current or in the Bottom Drift, up to and even beyond the Equator, provide high ways along which conditions of temperature, salinity and oxygen-content

remain remarkably constant, so that there is little or no barrier to the migration of genera or species that are capable of even a slight degree of adaptation to their surroundings. It thus seems probable that although in some instances the occurrence of the same species in the north Atlantic and the Indian Ocean may be due to the persistence in these two regions of a form that originally in early Tertiary times was continuously distributed through both areas and the intervening Tethys Sea, in other instances their distribution may be due to either active migration or to passive drifting from one ocean to the other along the deep high ways of the ocean currents and the discontinuity of their habitat may be apparent rather than real: but this problem must await a final solution till we know a great deal more about the fauna and flora around the Cape of Good Hope and the east coast of Africa on the one hand and the coasts of Antarctica on the other.

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AN OUTLINE OF THE GEOLOGICAL HISTORY OF INDIA.

By

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CONTENTS.

INTRODUCTION.

The three physical divisions of India

The most outstanding fact about the physical geography and geology of India, which in fact is the resultant effect of its late geological history, is the division of the country into three distinct segments of totally dissimilar characters: (1) The great, flat alluvial plains of Northern India extending from Sind to Assam—the India of legend and history; (2) the Peninsula of the Deccan, south of the Vindhyan mountains, a solid and stable block of the earth's crust, largely composed of some of the most ancient rocks of the earth, which the denudation of ages has carved out into a

number of mountain-ranges, plateaus, valleys and plains; and (3) the great mountain barrier which surrounds the plains to the west, north and east, known as the extra-Peninsula. The following differences summarize the main points of divergence between the last two regions. The first difference is *stratigraphic*, or that connected with the geological history of the areas. Ever since the Cambrian period, the dawn of geological history, the Peninsula has been a land area, a continental segment of the earth's circumference, which, since that epoch, has never been submerged beneath the sea except locally and temporarily. No appreciable marine deposits of a later age than Cambrian have been laid down in the interior of this land-mass. The extra-Peninsula, on the other hand, has been a region which has been underneath the sea for the greater part of its history, and has therefore been covered by successive marine deposits characteristic of all the geological periods commencing with the earliest, the Cambrian.

The stable Peninsula and the folded extra-Peninsula

The second difference pertains to the *geological structure* of the two regions. The Peninsula of India reveals quite a different type of architecture of the earth's crust from that shown by the extra-Peninsula. Peninsular India is a segment of the earth's outer shell that is composed, in great part, of generally horizontally reposing rock-beds that stand firm and immovable upon a stable and resistant foundation and that have remained so for a long cycle of ages, impassive and unfolded amid all the revolutions that have again and again altered the face of the earth. The only structural disturbance it has undergone is of the nature of lines of faults or fractures in the crust, due to tension or compression. The extra-Peninsula, on the contrary, appears to have been a weak and comparatively flexible portion of the earth's circumference that has undergone a great deal of crumpling and folding of the rock-beds indicating repeated upheaval and subsidence under the sea. The third difference between the Deccan and the highlands of Northern India is *physiographical* and arises from the two above-mentioned differences. In the Peninsula the mountains are mostly of the 'relict' type, *i.e.*, they are not true mountains of upheaval, but are mere outstanding portions of the old plateau of the Peninsula that have escaped, for one reason or other, the weathering of ages that has removed the surrounding parts of the land. Its rivers have flat, shallow valleys, with low gradients, because of their channels having approached to the base-level of erosion. Contrasted with these the mountains of the other area are all true mountains, owing their origin to a distinct axial uplift of the rock-beds. The rivers of this area, as a consequence, are rapid, torrential streams, which are still in a youthful or immature stage of river-development and are continuously at work in cutting down the inequalities in their courses and degrading or lowering their channels.

The Indo-Gangetic Plains, a depression

The third division of India, the plains of the Indus and Ganges, though humanly speaking of the highest interest and importance, as being the principal theatre of India's history, and a source of the great agricultural wealth of the country, is geologically speaking the least interesting part of India. In geological history it supplies only the annals of the last year, being composed of very late, sub-Recent alluvial and flood-plain deposits of the rivers of the Indus-Ganges system, borne down from the Himalayas and deposited at their foot. The plains have covered up underneath their deep mantle of clays, sand and silt valuable geological records which might have thrown light on the physical history and relations of the Deccan with the Himalayas. These plains were originally a deep depression, or furrow, which came into existence as a complement of the process of elevation of the Himalayan chain to their north. The filling up of this depression is the work of the latter part of the last geological age—the Pleistocene. The annexed table gives the main outlines of the succession of rock-systems in the different parts of India, arranged in the order of their age and referred to the standard divisions of the geological time-scale accepted for the world.

In the following pages we shall pass in brief review the rock-formations representative of the various geological periods that are found in India; in doing so we shall take into account their chief rock-components, their fossil contents, the geographical revolutions that took place during each age, the effect on the topography and scenery produced by the various systems of rocks and the important economic minerals associated with them.

Archæan System.

The Archæan is the name given to the oldest rock-system of the world, forming the very basement on which all the succeeding systems of the geological column rest. This system is believed by some to represent the first solidified crust of the earth, as it cooled from its original molten condition. The rocks are largely a mixture of gneisses, granites and schists, all thoroughly crystalline and permeated by injection of magma from the deeper, plutonic parts of the crust (orthogneisses and orthoschists). With these crystalline plutonic rocks are associated clastic sediments, which have undergone an extreme degree of metamorphism, due to heat and pressure of the earth's interior, and been converted into foliated crystalline rocks (paragneisses and paraschists). Owing to the conditions under which these rocks were formed and their subjection to mechanical deformations that have taken place in the surface layers of the earth, through the whole vista of geological time, the Archæan rocks have attained an extreme complexity of characters and relations in all parts of the world, which have not yet been

completely unravelled. The Archæan rocks cover three-quarters of a million square miles of the surface of Peninsular India, particularly Madras, Mysore, Orissa, the Central Provinces, Chota Nagpur and Rajputana. They extend north-westwards along the chain of the Aravalli mountains, one of the oldest mountain-ranges of the world, while they build, together with the intrusive granites of later ages, the central, snow-covered ranges of the Himalayas throughout its whole length, forming the very backbone of the mountains. All the high peaks of the Himalaya, from Nanga Parbat in Kashmir to Mt. Everest in Sikkim, are, however, largely composed of granite, which has pierced through this basement complex and is of much later age.

The fundamental gneisses

The great body of crystalline igneous rocks forming the Archæan gneissic complex of the Peninsula, either coarsely crystalline or finely foliated, is broadly classified into several regional units, such as Bengal gneiss, Bundelkhand gneiss, Peninsular gneiss, Charnockites, etc., as shown in the table given above, though no chronological order is implied in this grouping. The prevailing rocks are gneissose granites, charnockites (hypersthene-bearing eruptive rocks from granite to norite in composition), syenites, elæolite-syenites, anorthosites, granulites, calciphyres, calc-gneisses, marbles and hybridised manganese-bearing rocks (kodurite).

The scenery of the picturesque Nilgiri ranges, and of the low, straggling ranges of the Madras coast, the Shevaroys, Anaimalai, Palni hills, etc., is determined by the uneven weathering of the Archæan rocks. The Aravallis owe their deeply worn aspect to the denudation of ages removing the body of the mountains save the outstanding ridges.

Dharwar System.

The Archæan sedimentary rocks

The system of rocks named **Dharwarian** is closely associated with the Archæan gneisses and are probably of the same age. They are however chiefly of sedimentary origin, deposited in the hollows and depressions of the primeval crust, in which the first-formed seas of the world have collected their waters, on the condensation of the vapours that were held till then in the primitive atmosphere. The component rocks are mainly slates, hornblende- and chlorite-schists, quartzites, crystalline limestones and calc-granulites, charged with abundant and wide-spread granite intrusions. The Dharwarian system is best developed in Dharwar, the type area, parts of Mysore State, Rajputana, where it forms the outskirts of the Aravalli chain, in parts of the Central Provinces and Chota Nagpur, and in the belt of metamorphic sediments in the middle Himalayas. The Dharwar rocks of these different provinces illustrate varying characters. In the **Dharwar** district of Bombay,

from which the system takes its name, and in the Mysore State they occur in long narrow bands, the bottoms of compressed synclinals, the intervening anticlinal folds having been worn away. The constituent rocks are hornblende and other schists, slates, quartzites and brilliantly banded cherts. Numerous quartz-veins or reefs traverse these rocks, some of which are auriferous with a gold-content enough to support mining operations. The principal gold-mining centre in India, the Kolar fields of Mysore, is situated on these quartz-reefs.

Rajputana

The **Aravalli system** of Rajputana, consisting of varyingly metamorphosed limestones, phyllites, slates, quartzites and composite gneisses is one vast formation flanking the synclinorium stretching from Delhi to N. Gujarat, whose uplift at the end of the Purana Era has given rise to the most ancient mountain-chain of India. Overlying the Aravallis unconformably there comes another Archæan rock-formation, the **Raialo series,** chiefly marbles. The Archæans of Bihar and Orissa constitute what is known as the **Iron-ore series,** from its containing iron-ore bodies of large dimensions. These rocks are shales, slates and tuffs and banded hæmatite-quartzites containing massive or powdery hæmatite. The petrogenesis of the latter rock is a subject of some controversy. Considerable igneous action prevails, which has given rise to the chromite, asbestos and steatite of Singhbhum. A copper-bearing belt runs along a plane of overthrust in the schists and intrusive granite of Singhbhum. The Iron-ore series is underlaid by a group of crystalline limestones, schists and manganese ore-beds—the **Gangpur series.**

Bihar and Orissa

Central Provinces

The Archæan-Dharwar complex of the Central Provinces is also characterized by a metalliferous facies of deposits rich in ores of manganese. The country-rocks of the districts of Nagpur, Chhindwara and Bhandara are distinguished as the **Sausar series,** consisting of granulites, calciphyres, sillimanite-schists, and hornblende-schists carrying important aggregates of manganese-ores. The Sakoli series of the southern districts, consisting of less altered slates, chlorite-schists and jaspilites, is probably an upward extension of the Sausars. The famous marble-rocks of Jubbulpore as well as the richly manganiferous deposits of rocks, named by Sir L. L. Fermor, the **Gondite** series and the **Kodurite** series, also belong to this system.

Economic importance of Dharwar system

The Dharwar System is of great economic value to India : it carries the principal ore-deposits of the country, chief among which are the ores of gold, manganese, iron, copper, tungsten and lead, the Kolar gold-reefs producing 350,000 ozs. of gold per annum. The 3,000 million tons of high-grade iron-ore reserves of

Orissa, the manganese deposits which have supplied over 17 million tons of manganese-oxide to the world in the last 35 years, the copper and chromium lodes of Singhbhum, are all related to this system. To the same system belong economically useful minerals such as mica, corundum, graphite, and precious and semi-precious stones, *e.g.*, sapphire, ruby, beryl, zircon, spinel. The system is also rich in resources of ornamental marbles ; the famous Makrana marbles, used in the masterpieces of Moghul architecture, *e.g.*, those at Delhi and Agra, are a product of the Raialo series.

THE EPARCHÆAN INTERVAL.

The rock-formations grouped under the name **Purana group** roughly correspond in age with the Algonkian System of American geologists and succeed the Archæan after a profound regional unconformity. This unconformity is of great significance as it denotes the lapse of a vast interval of time, represented by many cycles of mountain-building and their erosion to the base-level before the lowest beds of the Puranas were deposited. The Purana rocks are a great thickness of pre-Cambrian unfossiliferous slates, quartzites, sandstones and limestones, found principally in the Aravalli chain, the Cuddapah area of Madras, and in the great escarpment of the Vindhya mountains in Central India. The classification of the group is given in the table facing page 45. The Cuddapahs and the Delhis are older and show a greater amount of tectonic plication and deformation than the Vindhyans, which are hardly disturbed from their original horizontal attitudes.

THE CUDDAPAH SYSTEM.

The type-area of the **Cuddapahs** is the district of this name in the Madras Presidency, where the system consists of 20,000 feet of indurated shales, slates, quartzites and limestones, with bedded lava-flows and tuffs. As in the Dharwars, there occur also brilliantly banded ferruginous jaspers and some manganese-ore. The whole group, though admirably adapted to contain and preserve organic relics, is totally barren of fossils. Workable deposits of barytes and asbestos occur in association with the Papaghni slates and limestones, the lowest member of the Cuddapahs, of the Ceded Districts of Madras.

THE DELHI SYSTEM.

A much higher degree of regional metamorphism and tectonic disturbance is visible in the **Delhi system,** typically exposed in the Aravalli mountains of Rajputana. It overlies the Raialos unconformably and builds the central axial zone of the Aravalli synclinorium, the part of the fold which experienced the most severe compression and depression. The Delhi System occupies a wide extent of Rajputana, extending in constricted, sorely eroded bands

from Delhi to Idar. The constituent rocks, aggregating 17,000 feet in thickness, are slates, phyllites, schists, quartzites, hornstone-breccias, arkoses and crystalline limestones. There is a considerable amount of igneous intrusions in the form of granite bosses and a varied suite of basic rocks. The Gwalior series, like the Bijawar series, which was formerly grouped with the Cuddapahs, is now regarded as homotaxial with the Aravalli, their comparatively lower grade of metamorphism being due to their distance from the axes of orogenic folding in which the Delhis are involved.

The Vindhyan System.

The next succeeding system, the **Vindhyan,** is in most of its area of extension an undisturbed formation, with generally horizontal stratification-planes, resting over the upturned and denuded edges of the underlying rocks. The Vindhyan sediments 14,000 feet in thickness, show two distinct facies of deposits—a lower argillaceous and calcareous (the **Semri series** of the Son Valley area) and an upper, almost exclusively arenaceous, divided into three series, the Kaimur, Rewa and Bhander series, of Central India. The lower Vindhyans show a certain amount of structural displacement and folding and are separated from the upper by an unconformity that is quite apparent in the north but which disappears in the southern areas of Mewar and the Son Valley. Homotaxial in position with the lower Vindhyans is the Malani series of volcanic rocks covering large areas of W. Rajputana. This series consists of partly glassy and devitrified, felsitic or amygdaloidal, rhyolites and quartz-andesites, interstratified with tuffs and volcanic breccias. The Malani series extends far northwards and is observed in some isolated hillocks near Sargodha in the Punjab alluvium. The characteristic Malani rhyolite is distinguished in the boulders occurring in the Upper Carboniferous glacial moraines at the base of the Productus Limestone of the Salt Range, a fact which indicates that the Aravalli mountains were the feeding ground of the glaciers that radiated out to distant parts of India during the Upper Palæozoic Ice Age. Connected with the Malani lava-flows, as their plutonic roots or magma-reservoirs, are the bosses of granite of Jalor and Siwana.

The Malani series

Contemporaneous formations with the Vindhyans are the Kurnool series of Cuddapah, the Bhima series of Southern Maratha country, the Pakhal series of the Godavari Valley and the Penganga beds of the Mahanadi Valley.

Other contemporary series

Life in the Purana Era.

The Cuddapah and Delhi rocks are devoid of all traces of animal or plant life, while the Vindhyan rocks, though so far they have not

yielded any specifically identifiable fossil remains, possess many indirect evidences of the presence of life at the period in fucoid markings, annelid casts and burrows, coaly layers, etc. Primitive life had already appeared on earth, and certain disc-like organisms, occurring in a black shale near Rampura, have been variously referred by different palæontologists to algæ or to valves of primitive brachiopods. In the very next succeeding Cambrian system we come across comparatively highly organized and diversified forms of invertebrates such as crustacea and molluscs, which give clear proof of a long course of antecedent evolution.

The Vindhyan system is of economic importance because of its unlimited resources in building stones of great beauty and durability. The famous 'Golconda' diamonds, for which India was once a much-sought market, were derived from some conglomeratic beds in the Upper Vindhyans, the original source of the diamond being probably certain basic dykes in the Cuddapahs or Bijawars.

The isolated mountain masses designated the Eastern Ghats, are composed of Archæan and Cuddapah rocks, while the series of steep escarpments which are such a feature of Central Indian scenery, are built of horizontally bedded sandstones and shales of the Vindhyan system. The **Aravalli** mountains received their last major uplift at the end of the Vindhyan period, for the Vindhyan strata flanking the Aravallis to the east are involved in the orogenic flexures. The plane of contact of the Vindhyans against the older rocks of the range is a 'boundary fault', traced for some hundred miles. All through the Palæozoic and Mesozoic this mountain range, stretching from Gujarat to as far as the Himalayas, was the most important feature in India's geography. At the present day, after the wear and tear of long ages, it is reduced to mere stumps of this once dominating chain.

The Palæozoic Era in India.

The **Dravidian Era** is unrepresented in the Peninsula in its entirety. In the Himalayas the whole group is found developed in a more or less continuous Palæozoic sequence of marine strata, which by reason of their fossil remains can be correlated with the European sequence with sufficient accuracy to warrant their designation by such names as Cambrian, Silurian, Lower Carboniferous, etc. Succeeding the Vindhyan Era in the Peninsula there is a great break in the geological sequence, in other words a number of geological ages pass away without leaving any record of rocks, signifying that no sedimentation took place during the interval but that the surface of the land was exposed to the action of the subaerial agents. This last interval, encompassing the whole of the Dravidian era, from the Cambrian to Upper Carboniferous, denotes another great *regional unconformity* in the geology of India.

In the extra-Peninsular mountains of Kashmir and Spiti in the Central Himalayas, there occurs a complete and conformable sequence of marine strata characteristic of the **Cambrian, Ordovician, Devonian,** Lower and Middle **Carboniferous.** A succession of marine faunas of brachiopods, trilobites, corals and cystoids enables a more or less precise classification and correlation of this series to be made with the Palæozoic divisions of the rest of the world. The best studied areas of Himalayan Palæozoics are Spiti and Kashmir ; the following table gives the succession in the two areas :—

	Spiti Valley	Kashmir
Upper Carboniferous	Productus series. Basal conglomerates.	Volcanic agglomerates, slates, containing *Gangamopteris*, fossil fish.
Middle Carboniferous	Po series—black shales with *Fenestella*, brachiopods and some fossil plants.—2,000 ft.	*Fenestella* series—quartzites, shales and conglomerates. Brachiopods, corals, polyzoa.—3,000 ft.
Lower Carboniferous	Lipak series—limestones and quartzites with brachiopod fauna.—2,000 ft.	*Syringothyris* limestone—flaggy limestone, shales and quartzites with locally rich fauna.—3,000 ft.
Devonian	Muth quartzites—well-bedded white quartzites, unfossiliferous.—3,000 ft.	Muth quartzites—snow-white series of unfossiliferous quartzites.—2,000 ft.
Silurian Ordovician	Coral limestones, dolomites, flaggy quartzites with cystoids and trilobites. Up. and Lr. Silurian.—2,000 ft.	Silurian of Lidar valley. *Orthis, Calymene, Phacops, Illænus*, etc.—100 ft.
Cambrian	Haimanta system—red and black slates, quartzites and dolomites. *Olenus, Microdiscus, Lingulella.*—2,000 ft.	Massive clays, sandy slates with limestone lenses. *Agnostus, Conocoryphe, Anomocare* of Upper and Mid. Cambrian affinities ; *Obolus, Acrothele, Lingulella.*—7,000 ft.

In the Salt Range mountains of the Punjab the **Cambrian** system is developed in the eastern scarps of the range, exhibiting the following section :—

Salt-pseudomorph shales—450 ft.

Magnesian sandstones, sandy dolomites, with *Stenotheca*—250 ft.

Neobolus shales—black, sandy shales with brachiopods, *Redlichia, Olenellus*, etc.—100 ft.

Purple sandstone—450 ft.

The Palæozoic land-period of India

Succeeding the Cambrian there occurs a big gap in the Palæozoic sequence of the Salt Range, the next overlying member being the basal beds of the Upper Carboniferous. This mid-Palæozoic unconformity is of wide prevalence in N.-W. Punjab, Hazara and W. Kashmir, in all of which the marine Silurian, Devonian, Lower and Middle Carboniferous are either absent altogether, or represented by isolated basins of unfossiliferous sediments of probably continental origin. Thus the enormous Dravidian land period of peninsular India also prevailed in some parts of Northern India. Since the creation of the Aravalli chain and certain minor systems of flexure in the Satpuras and on the East Coast, all mountain-building movements died down in the Peninsula and it has since remained a high and dry land-mass subject to some vertical movements of the crust, of the nature of dislocations, but not to any lateral or tangential movements of the fold-producing kind.

Geographical changes at end of Dravidian Era

The commencement of the Upper Carboniferous is a most important land-mark in the geological history of India. It ushered in an era of powerful earth movements and of profound geographical changes. In both the areas these changes were initiated by an **Ice Age,** which has left its characteristic marks at a number of centres over India in glacial boulder-beds and conglomerates. The extra-Peninsula witnessed a marine invasion and deepening of the sea-floor, on the present site of the Himalayas, from Hazara to Assam—the transgress of the great Mediterranean Sea from the west, the **Tethys** of geologists. There began to be deposited on the floor of this sea the vast pile of marine sediments which commenced with the Upper Carboniferous and ended with the Eocene, *i.e.*, the whole duration of the Aryan Era.

In the Peninsula, the end of the Dravidian and the beginning of the **Aryan Era** brought in different kind of earth movements and a new chain of events. Here the earth-stresses manifested themselves in producing tensional cracks and fissures and in the subsidence of large linear tracts, giving rise to chains of basin-shaped depressions in the old gneissic terrain. The drainage of the land discharging its load of sediments into these depressions, ultimately filled them up with a system of land and river deposits, burying in them countless remains of land-inhabiting plants and animals.

The Gondwana System of the Peninsula.

Thus, henceforth we have to consider a dual facies of deposits in India during the succeeding Palæo- and Mesozoic systems—a marine facies in the extra-Peninsula and a fresh-water and terrestrial facies in the Peninsula. This latter system of land deposits is

known in Indian geology as the **Gondwana System** from the typical basins of these rocks occurring in the Gond country to the south of the Narbada. It is of wide distribution in the Damodar, Mahanadi, and Godavari valleys, in the Satpuras, and in smaller patches in a number of far distant outliers in the Salt Range, Kashmir, Sikkim and Abor Hills. The accumulated drift of the dense forest vegetation which peopled Central India in those days has given rise to thick seams of coal 20 to 80 feet thick in the lower part of the Gondwanas, which thus constitutes one of the most productive geological horizons in India, supplying 23 million tons of coal per year. Some iron-ore also is associated with the coal seams. The Gondwana System is divided into two parts, Lower and Upper ; a thick zone of intervening strata, exhibiting intermediate characters, is sometimes separated as the Middle Gondwana division. The Lower Gondwanas range in age from the Permo-Carboniferous to the Trias. At its base is a glacial **boulder-bed** of wide-spread occurrence from Orissa to the Salt Range and Hazara, containing ice-scratched pebbles, testifying to the prevalence of glacial ice covering the land surface of India as far south as Lat. 20°. This is overlain by a thick series of coal-measures—the **Damuda series.** This series, at places 10,000 feet thick, and carrying the most important coal deposits of India, is divided into :—

Coal-measures of the Lower Gondwana

Raniganj stage.
Ironstone Shale, or Barren Measures stage.
Barakar stage.

These stages are well recognized in the Damodar valley, but are not easily identified in the other Gondwana areas, where they are designated by a number of local terms. The Damuda series is overlain by the **Panchet series** of greenish sandstones and red shales with some coal-seams, containing fragmentary remains of labyrinthodonts and reptiles. A prolific flora (the *Glossopteris* flora) in which the preponderant element was the seed fern, *Gangamopteris*, *Glossopteris*, etc. together with some *Cordaitales*, characterizes the Damuda series. The Middle and Upper Gondwanas evince a change of physical conditions from the arctic cold of a glacial epoch to a semi-desert type of climate and the disappearance of the luxuriant forest vegetation of the earlier epoch. The prevalence of thick red, iron-stained sandstones and shales point to a drier and warmer climate. From the evidence of the contained fossils of reptiles and of plants, with a preponderance of the coniferous and cycadaceous orders of the gymnosperms, the geological range of the Upper Gondwanas is determined to be from Upper Trias to Lower Cretaceous. The

Changes in climatic and physical conditions

ferns, horse-tails and seed-ferns of the lower division are replaced by conifers and cycads, and in one or two cases by a still higher order of plants, in the Upper Gondwanas, while the fishes and labyrinthodonts are succeeded by reptiles.

Distribution of the Upper Gondwanas

The Upper Gondwanas of the Satpura area, well exposed in the gigantic scarps of the range, are distinguished as the **Mahadeva** or **Pachmarhi series,** mostly composed of sandstones, 10,000 feet in thickness. In the Godavari valley a similarly constituted group is named the Kota-Maleri series, containing the fish *Ceratodus* and the reptiles *Parasuchus* and *Hyperodapedon*. In the Rajmahal hills a quite different rock-facies prevails—2,000 feet of basaltic lava-sheets interbedded with shaly sediments containing a well-preserved flora, some members of which have reached the stage of evolution of angiosperms and hence mark an uppermost Jurassic or Lower Cretaceous horizon. A similar age is ascribed to the Upper Gondwanas of Cutch, the Umia beds, which contain along with a Gondwana flora, intercalated marine beds with *ammonites* of Neocomian horizon. Upper Gondwanas outcrop at a few places on the East Coast containing fossil plants of Rajmahal affinities; they also are associated with marine intercalations entombing *Trigonia* and *ammonites* of Lower Cretaceous age.

The Gondwana system of river deposits, occurring in scattered basins, which continued to sink *pari passu* with deposition for such a long section of geological time, is of unique significance and illustrates the peculiar physical structure of the Indian sub-continent. During this period in the Tethys Sea, bordering Gondwanaland to the north, there were being deposited marine sediments bearing characteristic fossils pertaining to the ages Permo-Carboniferous, Permian, Trias, Jurassic and Cretaceous.

Parallel deposits in Africa and Australia

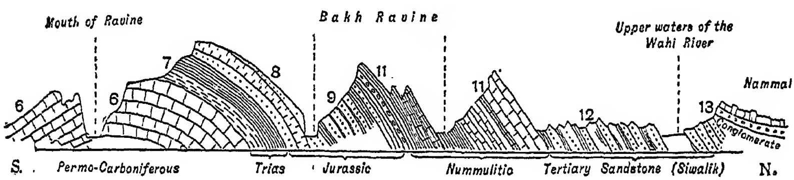
A more or less similar group of river-borne land deposits, containing coal-measures and commencing with a glacial conglomerate at the base, is found in Australia, Madagascar and South Africa, containing a fossil flora which possesses many affinities with the Indian Gondwana flora. Some marine inclusions near the base of the series, occurring in the Salt Range, Kashmir and in New South Wales (Australia), contain closely related species of *Eurydesma*. From this fact, as well as from important discoveries of nearly allied species of fossil reptiles in the Jurassic and Cretaceous of India, Africa and Patagonia, it is argued that land connections existed between these distant regions, across what is now the Indian Ocean, either through one continuous southern continent, or through a series of land-bridges and isthmuses, which extended from South America to India and united within its borders

An old Indo-African continent

the Malay Archipelago and Australia. To this old-world southern continent the name of **Gondwanaland** is given. This continent persisted as a prominent feature of the Southern Hemisphere from the end of the Palæozoic, through the whole length of the Mesozoic, to the beginning of the Cainozoic, when it disappeared as an entity by fragmentation and drifting away of its constituent blocks, or by their foundering. The north frontier of this Indo-African continent was the shore of the Himalayan sea, the Tethys, which stretched from the south-west extremity of China to the present Mediterranean.

THE MARINE PERIOD OF THE EXTRA-PENINSULA.

A totally different sequence of geological events was taking place in the extra-Peninsula during the Gondwana Era, resulting



TEXT-FIG. 1.—A typical transverse section across the Salt Range showing sequence of strata from Upper Carboniferous to Tertiary (Scale: 3 inches = 1 mile).

in the formation of a quite different set of rocks which have preserved in them a wealth of the marine animal population that was contemporary with the various stages of the Gondwanas. The Permo-Carboniferous and Permian chapter in this history is represented in the Salt Range by one of the most perfect marine developments seen anywhere in the world. Every stage in the sequence, from the Uralian to the uppermost Permian, grading imperceptibly into the Trias, is present, bearing its characteristic suite of fossils. The Salt Range succession begins with a boulder-bed or till, composed of striated and facetted boulders of crystalline rocks from the south, embedded in a silty matrix. This is overlaid by olive shales and sandstones (*Conularia* beds) containing *Eurydesma* and other fossils allied to those of the glacial beds underlying the coal-measures of New South Wales. An overlying group of mottled sandstones and clays has preserved impressions of *Gangamopteris* and *Glossopteris*, genera so wide spread in the Lower Gondwana areas of the south-east. The next formation is about 700 feet of deeper water marine limestones still containing occasional intercalations

of plant-bearing beds, differentiated into three well-marked divisions, Lower, Middle and Upper **Productus Limestone,** each again sub-divided into stages and zones dominated by some species of *Productus* or, in the upper stages, by some precocious genera of *ammonites*. Among the brachiopods characteristic of the Lower Productus are *P. spiralis*, *P. semireticulatus*, *P. cora*, associated with the aberrant genus *Richthofenia* and the foraminifer *Parafusulina*. The commonest Middle Productus forms are *P. lineatus*, *P. indicus* with *Oldhamina* and *Lyttonia*; *Xenodiscus* occurs with this division, together with *Coboceras* and *Foordiceras*. The Upper Productus Limestone marks still more the approach of Trias by the presence of many genera of true ammonites, *e.g.*, *Cyclolobus*, *Medlicottia*, *Popanoceras*, *Tænioceras* and *Arcestes*.

Permo-Carboniferous, Permian and Mesozoic of the Salt Range

The occurrence of Lower Gondwana plants in close association with marine fossils at the base and middle of the Productus limestone is an event of much importance and serves to fix the lower limit of the Gondwana System as well as the age of the Palæozoic glaciation of India within narrow limits. An exactly similar association of Damuda plant-beds in several localities in Kashmir with volcanic slates and tuffs of the Panjal Volcanic series, fortunately dated by the occurrence in them of crowds of species of *Productus* and *Spirifer* at two or three distinct levels, and their superposition by the marine Zewan series, correlated by Cowper Reed with the Middle Productus horizon of the Salt Range, further supplements this evidence.

The long marine history of the Himalayas during the Aryan Era

In the broad, slowly sinking ocean floor of the Tethys, during this interval, a great thickness of shales and limestone, crowded with lamellibranchs, crinoids and ammonites was being laid down. The rate of deposition keeping pace with the submergence of the ocean-bottom, there has resulted a pile of thousands of feet of shallow-water as well as deep water strata representative of the **Permian, Trias, Jurassic, Cretaceous** and **Eocene** periods. The following table summarizes in bare outline the main chapters in the marine Himalayan record as it is laid bare in the great escarpments of the Tibetan plateau :—

Eocene	**Nummulitic limestones** and shales of Ladak and S.E. Tibet, with contemporaneous basic volcanics ..	2,000 feet.
Cretaceous	**Chikkim series** of white limestones and shales; **Giumal series**: Flysch of Central Himalaya; Volcanic series of Burzil and Dras; Massive acid and basic plutonics ..	6,000 feet.
Jurassic	**Kioto limestone** and dolomites overlain by the **Spiti shales** from Hazara to east of Nepal ..	4,000 feet.

Triassic	Lower, Middle and Upper **Trias** commencing with the **Otoceras zone**; limestones, dolomites and shales of Kashmir, Spiti, Garhwal and Kumaon	5,000 feet.
Permian	**Productus Limestone,** Kuling and Zewan series; Sirban limestone, Krol limestone of the Outer Himalayas	3,000 feet.
Upper Carboniferous	**Panjal Volcanic series** of Kashmir with marine and Gondwana intercalations; Infra-Krol series. Glacial conglomerates of Simla **(Blaini series)** and of Hazara (Tanakki beds)	8,000 feet.

The lateral zoning of the Himalayas

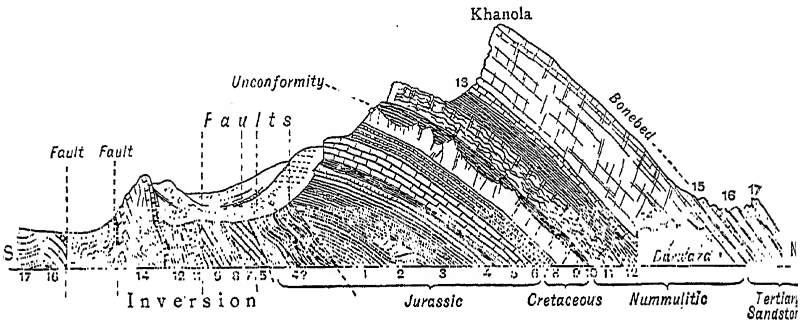
The above section of strata, particularly from the Trias upwards to the top of the Cretaceous, together with the underlying equally interesting Palæozoic section from the Cambrian to Middle Carboniferous, is exposed in the series of magnificent escarpments to the north of the central Himalayan axis, in Spiti, Garhwal and Kumaon and further east in Sikkim, where the Tibetan plateau ends in gigantic cliff faces. This is known as the **Tibetan Zone** of the Himalayas in distinction to the central or **Himalayan Zone** of unfossiliferous slaty and crystalline rocks building the middle ranges of the mountains, and the outer or **Sub-Himalayan Zone** composed mainly of middle and upper Tertiary. The long and uninterrupted Himalayan marine period, from the Uralian to the middle Eocene, preserving successive dynasties of fossil faunas, showing kinship with the Alpine and other European Mesozoic areas, is a notable event in earth-history and marks out the Tibetan sections as some of the most perfect and legible expositions of the stratified crust of the earth. There are no unconformities or lost intervals in the sequence; the Aryan era of the Himalayas thus runs astride the limits of the Mesozoic Era of the standard geological scale. Their inaccessibility behind the lofty central ranges is, however, a great drawback, a difficulty only removed in part by the more accessible sections exposed in the Kashmir mountains. The Kashmir sections, however, are partial and not so continuous; they are also often concealed under glacial and other debris.

The Himalayan geosyncline

Portions of the sea-floor subsiding in the form of immense troughs, concurrently with deposition of great thickness of sediments, as in the above example, are called geosynclines. The immense accumulation of strata in geosynclines ultimately disturbs the gravitative equilibrium of the crust and during the next succeeding periods of earth-deformation these loaded and consequently weakened belts come to be wrinkled up to form the mountain-chains of the world.

They are thus singled out as the weaker and more flexible portions of the earth's circumference, in contrast with the stable and rigid blocks such as the Peninsulas of Africa and India (horsts).

In contrast with the unique Mesozoic development of the geosynclinal facies of the Himalayas, the records of the Salt Range Mesozoic are patchy and consist of coastal shallow-water deposits. Only the lower Trias (*Ceratite* beds) is represented, overlain by middle and upper Jurassic beds exhibiting a rapidly varying lithology, enclosing some coal-seams. The Cretaceous (Neocomian) is of inconspicuous thickness and extent, being restricted to the trans-Indus extension of the Range.



TEXT-FIG. 2.—Section showing inverted folding and faulting, Chichali, Shekh Budin hills.

MARINE TRANSGRESSIONS IN THE PENINSULA.

To revert to the Peninsula's history of the Aryan Era, interrupted since the close of the Gondwana period. There occurred during the Jurassic and Cretaceous several minor inroads of the sea on the coastal fringes of the Indo-African continent, which was probably not yet dismembered. In one of these in the Upper Jurassic in Cutch there was laid down 6,000 feet of fossiliferous limestones, marls, and sandstones preserving a highly diversified but more or less provincial cephalopod fauna, which has enabled a fourfold division of the rocks into Patcham, Chari, Katrol and Umia series, ranging in age from Bathonian to the Neocomian. This marine invasion penetrated as far north-east as Jaisalmer in Rajputana. 114 genera and 600 species of ammonites have been identified, of which a great many are purely local types unknown elsewhere. Of the rest, the Cutch Jurassic fossils present no affinities with the Mediterranean or north-west European province, but they show kinship to the Jurassic faunas of Madagascar. In another of these transgressions of the sea, the Trichinopoly coast was submerged and covered with some 3,000 feet of richly fossiliferous grits, sandstones and clays, in which are preserved more than 1,000 species of marine molluscs, the majority of them being ammonites,

Cretaceous marine deposits

disclosing close relationship with the Cretaceous of Madagascar and Natal. Four well-marked stages are recognized in the Trichinopoly Cretaceous, whose correlation with the European stages is shown below:—

Niniyur stage with *Nautilus danicus*..........	Danian.
Ariyalur stage with *Trigonoarca galdrina*....	Senonian.
Trichinopoly stage with zonal distribution of *Placenticeras* and *Pachydiscus*............	Turonian.
Utatur stage with zones of *Mammites*, *Acanthoceras* and *Schloenbachia*............	Cenomanian.

Assam and the Narbada valley witnessed similar temporary invasions of the sea during the Upper Cretaceous, vestiges of which are seen in patches of marine deposits containing fossils characteristic of the time. In the Narbada valley these are known as **Bagh beds.** The Bagh fossils are distinct types, showing greater affinity with the Cretaceous of Arabia and Europe than with the adjacent Assam or Trichinopoly province. This dissimilarity shows that the two seas were still separated by some great and far-reaching land-barrier. The **Lameta beds** are a thin zone of fresh-water and estuarine beds of the same or slightly newer age than the Baghs, covering a wide extent of the ground underlying the Deccan Trap. They are of stratigraphic value by reason of their infra-trappean position and the 12 genera of Dinosaurian reptiles that are preserved in them.

THE DECCAN TRAP VOLCANIC PERIOD.

At the end of the Cretaceous, and according to recent discoveries, well after the commencement of the Eocene, the Deccan experienced a period of intense volcanic activity of a type that has no parallel among the volcanic phenomena of the modern world. Several hundred thousand square miles of the country were flooded by quiet outpourings of basaltic lava from fissures in the earth's surface which was eventually converted into a plateau several thousand feet high **(Deccan Trap).** The denudation of ages has carved out this plateau into numerous isolated, flat-topped and square-sided hill-masses which are to-day such a feature of the landscapes of the Western Ghats. In the dissected sides of these peculiar ghat-shaped hills we see to-day the piles of bedded basalts, in 20 to 80 feet thick horizontal flows, separated by thin partings of sediments, **inter-trappean beds.** The inter-trappean beds are fossiliferous and are thus valuable as furnishing the history of the periods of quiescence which intervened between the volcanic outbursts and of the animals and plants that again and again migrated to the quiet centres. Numerous palms and some flowering plants, together with fishes, frogs, and various orders of reptiles flourished at this period in the Deccan, the petrified remains of

which, from this and adjoining areas, bear witness to the advanced, more evolved forms of life that superseded the land life of the Gondwana period.

The Deccan trap magma is generally an undifferentiated amygdaloidal basalt, or dolerite, of normal composition, but there are a few centres, *e.g.*, Girnar in Kathiawar and Pawagarh hill near Baroda, where acid and ultra-basic variations of the prevailing magma are met with, both in their intrusive and extrusive forms. A host of zeolitic and secondary minerals have been noted in vesicular cavities, as well as interstitially, in the lavas. Ash-beds are common, with a few glassy and pumicious forms of lava, but agglomerates and coarse tuffs are absent, thus excluding any signs of explosive volcanic action during the eruptions. Swarms of dykes of dolerite traversing the bedded flows for long distances and extending through the bordering terrain are seen all along the periphery of the trap area, marking the sites of the fissures of eruption.

Probably associated with the Deccan trap eruptions are the early Tertiary gabbro, peridotite and granophyre intrusions of Baluchistan, carrying the important chromite segregations of the Quetta and Zhob districts, and the serpentinized peridotites of Burma, with their included masses of the much-prized mineral jade.

Geography of India at beginning of Tertiary Era.

The Deccan traps mark the advent of the **Cainozoic** or **Tertiary Era** *of earth-history.* Great changes in physical geography adumbrate the new era ; of these the most momentous were the breaking up of Gondwanaland into the now severed lands of Africa, India, and Australia, and the initiation of earth-movements which culminated in the lifting up of the Himalayan geosyncline from the bed of the Tethys Sea into the loftiest mountains of the world. It is probable that the outpouring of thousands of feet of Deccan trap lavas from the interior of the earth was in some way a prelude to the stupendous release of geodynamic energy in later Tertiary times. The backbone of Tertiary India, its main water-shed, was the Vindhya range with the Kaimur hills continued north-east by the Hazaribagh-Rajmahal hills and the Assam ranges. This water-divide separated the northerly drainage flowing into the remnant of the Tethys (left after the first mid-Eocene uplift of the Himalayas) from the southward flowing drainage into the Indian ocean. There were then two principal gulfs—the Sind gulf, extending north through Cutch, Punjab, Simla and Nepal ; and the eastern gulf of Assam and Burma, separated into two by the meridional ridge of the Arakan Yoma. The Gangetic plains were then a comparatively featureless expanse of rocky country, sloping northwards from the central Indian highlands towards the Sind gulf.

MARINE AND DELTAIC FACIES OF THE TERTIARIES.

The Tertiary history of India is recorded in the thick sedimentary deposits filling these two gulfs. As these dwindled and receded, they were replaced by the broad estuaries of the rivers that succeeded them, *e.g.*, the Indus in the former case and the Ganges and Brahmaputra in the case of the latter. The earlier marine deposits were steadily replaced by the growing estuarine and deltaic sediments of the rivers superseding them.

Except for a few small patches near the coasts, the Tertiary deposits of India are restricted to the extra-Peninsular mountains. The ranges of Sind, Assam and Burma, and the sub-Himalayan zone, along its whole length, are almost entirely composed of these rocks, of which the lower, Eocene and Oligocene, are marine, while the upper, Miocene and Pliocene, are of fresh-water and sub-aerial deposition. In the Sind hills, the area taken as the type of the Tertiary succession for the rest of India, the group is classified as follows :—

Manchar series (Siwalik) 10,000 feet.	Grey and brown sandstones and conglomerates with fossil mammals.	Up. Pliocene.
Gaj series 15,000 feet.	Marine limestones and shales overlying fresh-water strata, with land-mammals.	Up. Miocene. Lr. Miocene.
Nari series 6,000 feet.	Upper part, fresh-water sandstone; lower part, marine limestones with foraminifera.	Oligocene.
Kirthar series 9,000 feet.	Massive Nummulitic limestones and shales, highly fossiliferous.	Upper Eocene.
Laki series 800 feet.	*Alveolina* limestone with calcareous shales and coal-measures.	Mid. Eocene
Ranikot series 2,000 feet.	Marine foraminiferal limestones underlain by coaly and gypseous shales.	Lower Eocene.
	Cardita beaumonti beds ..	Upper Cretaceous

Salt, Coal and Petroleum associated with Eocene and Miocene

A more or less full sequence of Tertiary rocks is met with in the Salt Range, the Potwar plateau, the Punjab foot-hills, Assam and Burma, many of whose stages are correlatable to the Sind sequence. The lower part of the Tertiary is of economic value because of the association of rock-salt, coal and petroleum with the Eocene and Miocene rocks of Punjab, Assam and Burma. The rock-salt occurs in beds up to some hundred feet thickness in the Laki series of the Salt Range, in the adjacent Kohat area and in the Mandi State near Simla. The rock-salt mines of these localities supply 170,000 tons of salt annually, the whole of which is used for human consumption. About 450,000 tons of coal is mined from the coal-measures of the Ranikot-Laki series, while petroleum is the product of a somewhat higher horizon (Oligo-

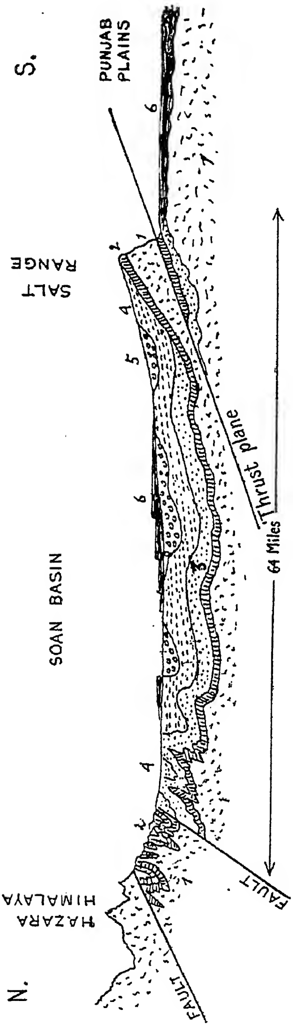
cene to Miocene) yielding nearly 250 million gallons from the Burma oilfields and 53 million from Assam, per year. The Khaur and Dhulian oilfields on the Punjab Tertiaries, producing 15 million gallons yearly, derive their oil from the Eocene Nummulitic limestone and overlying Murrees.

The fossil wealth of the Siwalik System.

The most important upper Tertiary formation, from the palæontological point of view, is the **Siwalik System** (Lower Miocene to Lower Pleistocene). It is a group of river and subaerial deposits, sand-rock, clays and conglomerates, 16,000 feet thick, of remarkable uniformity of composition and character, stretching in a long continuous band from Sind, through the Punjab (where it attains its greatest width), to Nepal and Assam. The Siwaliks are constituted of the debris brought down from the newly upheaved Himalayas by the numerous transverse rivers and deposited in the broad valley of a north-westerly flowing river, which carried the combined discharge of the present Brahmaputra, Ganges and Indus to the head of the Sind gulf. This river is named *Indobrahm* by Sir E. Pascoe. This system is noted for the wealth of fossil species belonging to extinct families of elephants, rhinoceroses, horses, giraffes, pigs, apes, deer, antelopes, bovids, camels and carnivores; these animals are not far distant in age from our time and therefore are the immediate ancestors of our existing land mammalia. The prolific remains of their skeletons, skulls, teeth, bear witness to the abundance of the higher terrestrial life of those days before which the present world looks impoverished. The Siwaliks have preserved the remains of nearly 15 genera of anthropoid apes, the highest mammal in the then existing living world, some of which are believed to be links in the line of human ancestry, and it is possible that future research may bring to light some remains of Primitive Man from the top beds of the Siwaliks.

Pilgrim has classified the Siwalik system as follows, based on various mammaliferous horizons :—

Upper Siwalik 6,000–9,000 feet.	Boulder-conglomerate stage—coarse conglomerates, or thick, earthy clays: *Elephas, Equus, Bos.*	Lower Pleistocene.
	Pinjor stage—*E. planifrons, Hemibos.*	
	Tatrot stage—*Stegodon, Leptobos*	Up. Pliocene.
Middle Siwalik 6,000–8,000 feet.	Dhok Pathan stage—massive sandstone and sand-rock; *Hipparion, Giraffoids, Hippopotamus, Stegodon, Mastodon.*	Pontian.
	Nagri stage—*Hipparion, Prostegodon* ..	Sarmatian.
Lower Siwalik 4,000–5,000 feet.	Chinji stage—deep, red, nodular clays with few sandstones; *Tetrabelodon, Giraffokeryx, Listriodon, Mastodon, Dinotherium.*	Tortonian.
	Kamlial stage—dark, hard sandstones with purple clays; *Anthracotheroids, Aceratherium.*	Helvetian.



TEXT-FIG. 3.—Section across the Potwar Geosyncline.

(1) Pre-Tertiary; (2) Eocene; (3) Murree Series; (4) Lower Siwalik; (5) Upper Siwalik; (6) Sub-Recent.

Three phases of uplift of the Himalayas.

With the end of the Siwalik epoch the last phase of Himalayan upheaval was completed, for at many localities in the foot-hills tightly folded upper Siwalik strata stand on edge, or have been thrust over later Pleistocene alluvium. The two earlier phases of Himalayan uplift were (1) the post-Eocene, which drove back the last remnants of the Nummulitic sea of the Himalayan area and upheaved the ocean floor to rise in one system of crustal folds. The nummulitic limestone is at places elevated 15,000 to 20,000 feet; (2) post-Miocene, which raised the zone of Murree-Kasauli sediments into the lesser Himalayan zone, imparting to it complicated flexures and thrusting it under the older Tertiaries.

The parallel lines of reversed faults in the Tertiary zone of the sub-Himalayas of the Punjab, Kumaon and Nepal designated as the 'Boundary Faults' by Medlicott and Middlemiss, mark the periodic uplift of the mountains accompanied by the encroachment of the mountain-foot more and more towards the rapidly filling depression to its south.

Recent views about structure of the Himalayas

Recent work in the Kashmir, Simla and Garhwal Himalayas has thrown some light on the structural plan of these mountains and revealed the existence of thrust-planes of great magnitude, by which immense recumbent sheets (*nappes*) of the inner Himalayas have slid forward and come to lie on the newer rocks of the outer zone. At least two such thrusts have been clearly marked, one along which the younger Tertiaries of the sub-Himalayas are brought either against the Nummulitics or Permo-Carboniferous (Panjal or Blaini or Krol series) and another, along which the latter are overthrust by the great recumbently folded sheets of the crystalline and metamorphic Purana, or still older sediments, of the inner zone. The roots of the latter nappes, or sheet-folds, are not autochthonous, but lie much to the north in the central axial zone of the Himalayas.

The Quaternary Ice Age.

The end of the Siwalik epoch witnessed, in common with many regions of the northern world, a great refrigeration of climate which culminated, in the Himalayan region, in an **Ice Age**, during which the greater part of the land surface was buried under a cap of ice. In the rest of India, situated below Lat. of 30°, the cold was not intense enough to cause glaciers to flow over its surface but it gave rise to a succession of cold, rainy periods (Pluvial period) which induced notable changes in the habitat and distribution of the then living fauna and flora of the Peninsula. In the Himalayas the records of the Quaternary ice age are clear,

both in the glaciated topography of the valleys and ranges and in the accumulations of moraines, erratics, rock-striations, roches moutonnées, etc.

FORMATION OF THE INDO-GANGETIC TROUGH AND ITS FILLING UP.

The Indo-Gangetic Alluvium: The geotectonic stresses involved in the erection of the Himalayas produced in the northern part of the Peninsular foreland a concomitant sag or depression, at the foot of the mountains. This wide trough between the Vindhyan-Kaimur highlands and the northern mountains was, in the Eocene time, occupied by an arm of the sea; the scattered chain of nummulitic outcrops, extending from Naini Tal to the Kala Chitta hills near the Indus, are the memorials left by that sea. As this sea gradually retreated after the Eocene it was superseded by the broad estuary of the north-westerly flowing river referred to on p. 62, which traversed the whole breadth of India from Assam to the north-west corner of the Punjab and then turned south to discharge into the Sind gulf. It was in this river-basin that the Murree and Siwalik series were formed. This north-westerly drainage was disturbed in mid-Pleistocene time by differential earth-movements and the old great river was dismembered into the three separate river-systems of the Indus, Ganges and Brahmaputra. The depression still left began to be filled up by the silt brought down from the high ground by the hydra-headed tributaries of the Indus and Ganges. Each fresh uplift of the mountains must have rejuvenated the streams, thus multiplying their carrying capacity and aggrading power. On emergence from the steep gradient of their mountain-track, these streams discharged their burden into the depression, eventually filling it up and converting it into the low, flat, level plains of the Punjab, the United Provinces, Bihar and Bengal.

Estimates about the depth of the alluvium in the Indo-Gangetic trough vary from 6,500 feet to 15,000 feet. The trough is not of uniform depth along its whole length; it is probably at maximum depth between Delhi and the Rajmahal hills and shallow in Rājputana and Assam. Nor is the floor smooth, for several corrugations and ridges have recently been observed underneath the alluvium by gravimetric surveys carried out by the Geodetic Survey of India. The northern rim of the trough, where it merges into the Himalayan foot-hill zone, is one of considerable tectonic strain; it is the site of the long parallel fractures of boundary fault type (p. 64) and it is conceivable that the alluvium conceals a zone of similar folding and faulting further south. The seismic belt of India runs along the north margin of the plains; the epicentres of the majority of the great Indian earthquakes since the XV Century lie in this zone.

The earthquake belt of India

LATERITE.

The peculiar rock-formation known as **Laterite**, occurring as a cap over the surface rocks of tropical, monsoon-swept countries, is of wide distribution in the peninsular part of India from Assam to Cape Comorin. It is a reddish or mottled vesicular clayey rock, pisolitic or massive, composed of a mixture of hydrated oxides of alumina and iron, with smaller percentages of other oxides. There is generally no clay in typical laterite, the silica present is colloidal, mechanically held and not combined with alumina as kaolin. The base of many laterite deposits is bauxite and there are numerous varieties of laterite which have a large proportion of bauxite at one end and an indefinite mixture of iron hydroxides at the other end of the series. The rock is subject to many secondary chemical and segregative changes and hence presents numerous modifications in the field. Laterite occurs principally as a superficial cap on the basalt of the Deccan highlands but it is not confined to this rock and overspreads other formations as well. It caps plateaus ranging in height from 2,000 to 5,000 feet, the thickness of the cap varying from 50 to 200 feet commonly. Laterite deposits have economic value, being used at places as ores of iron or aluminium, as a source of aluminous cement and, from the facility with which it can be cut, when fresh, into blocks, as a building and road-making material.

SUB-RECENT.

Among the deposits that belong to geologically recent or sub-recent age may be mentioned the following diverse kinds: the high-level terraces of the principal rivers, coastal deposits, some raised beaches and submerged forests, wind-blown sands (of the Rajputana and Cutch deserts), loess, some cave-deposits, the black cotton-soil of Gujarat and Deccan, the ossiferous gravels of the upper Sutlej and Narbada and the Karewas of Kashmir. With many of these are associated relics of Prehistoric Man in India, his rudely fashioned knives, scrapers, celts, etc., made out of stone metal or bone. The principal sites from which palæolithic implements have been derived are the valleys of the Godavari, Narbada, Mahanadi and the Potwar plateau of N.-W. Punjab. Here we reach the limit of geological history; further inquiry lies in the domain of Archæology and Anthropology.

TWO TYPE-AREAS FOR GEOLOGICAL STUDY IN INDIA.

In the above sketch of the geological history of India we have presented only a broad generalized account of the sub-continent in its barest outline. In by far the greater part of the country, the part in which the chief centres of population with their schools and universities are situated, the geological record is

highly imperfect and dis-continuous. Occurring in remote, fragmentary patches, the geologist's opportunities for field observation and study of this essentially out-of-doors science are greatly restricted. There are two localities in India, however, where the student of geology will find a considerable section of the most interesting divisions of the geological record laid bare in accessible sites. These two localities are: (1) the Salt Range mountains, and (2) the Valley of Kashmir.

Geological phenomena seen in the Salt Range.

The **Salt Range** is a continuous range of low, flat-topped mountains rising abruptly out of the Punjab plains. It extends from Long. 71° 30′E. to 73° 30′ with an approximately E.-W. strike from the Jhelum river to the Indus. It is a most important locality in India for the study of physical as well as stratigraphical geology, not only because it contains a very large portion of the stratified record of the Indian region, but because of the easily accessible nature and the clearness of the various sections laid bare in its hill-sides and valleys. Besides its stratigraphical and palæontological interest there is inscribed in its barren cliffs and dry gorges such a wealth of illustrations in dynamical and structural geology that this imposing line of hills can fitly be called a field-museum of geology. The striking structural feature of the Salt Range, a disrupted and thrust-faulted monocline, is the more or less level plateau top, ending on the one side in a line of steep escarpments overlooking the Punjab plains, and on the opposite, northern side, inclining gently towards the Kala Chitta hills and enclosing between them the Tertiary geosyncline of the Potwar. The general dip of the strata being to the north, the youngest Tertiary rocks are seen in the northern dip-slopes, while in the steep southern escarpments is exposed the fine succession of strata beginning with the Cambrian, through the Carboniferous, Permian, Trias, and Jurassic to the top of the Eocene, though the sequence is repeatedly interrupted and inverted by thrust-faulting.

The entire length of the range is faulted in a most characteristic manner by a number of transverse dip-faults into well-marked clean-cut tilted blocks. More important faults, regarding the tectonics of the range, are the reversed strike faults, often intensified into thrust-planes, by which slices of Cambrian strata have been repeatedly overthrust on to the Eocene, and these again over newer rocks. Recent work has made it clear that the foot of the range has undergone a horizontal displacement of many miles, being moved by pressure acting from the north along a gently inclined thrust (nappe).

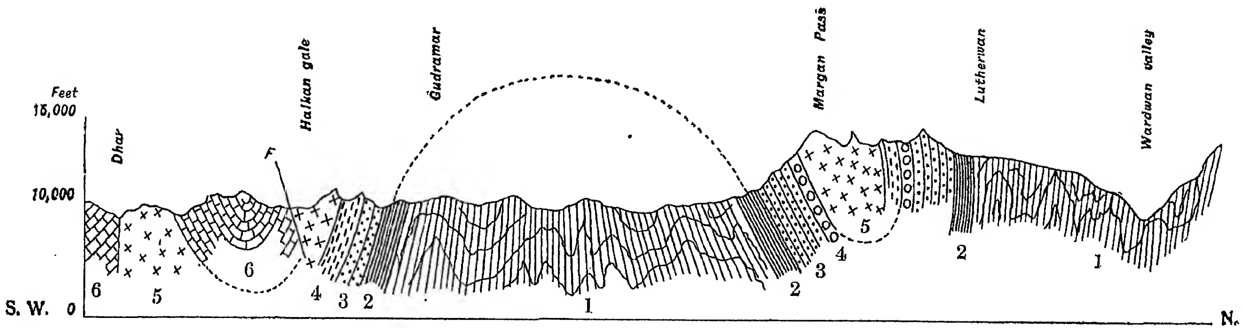
The name Salt Range is derived from the fact that its lowest beds, at the bottom of the cliffs, contain layers and lenses of pure rock-salt. Though occurring at the foot of the sections, this

position of the salt is adventitious and is due to the thrust-fault mentioned above.

Facilities for stratigraphic and tectonic work in the Kashmir Himalayas.

The **Kashmir Valley**: Kashmir possesses within a small geographical compass one of the best developments of the stratified geological record. A complete series of fossiliferous formations, from the Cambrian to the Trias is exhibited in the mountains immediately surrounding the beautiful valley, in localities accessible to the student and thus offering opportunity for stratigraphic work met with in no other part of India, except the Salt Range. The Kashmir mountains are a unique excursion ground as much for stratigraphic investigation as for their orographic and physiographic features, glaciers, lakes, etc. Representatives of all the major units of the geological column are present in the area. Of these, the upper Tertiary is well displayed in the foot-hills of Jammu, adjoining the Punjab, while the older Tertiaries are exposed in the outer ranges of the middle Himalayas. The whole of the Palæozoic, together with a grand development of the Trias is observed in the northern mountains, flanking the wide synclinal basin of the upper Jhelum valley. It is only for the study of the Jurassic and Cretaceous that the student has to go farther afield and to penetrate to the central ranges of the inner Himalayas.

In the orthoclinally built Pir Panjal range, forming the southern flank of the Jhelum valley syncline, the steep south-west face exhibits clear sections revealing the tectonics of this part of the Himalayas, its thrust-planes and great recumbent folds, while the gently inclined north-east slopes, covered under enormous glacial and lacustrine (Karewa) deposits afford excellent ground for study of Pleistocene geology and recent orogenics. It is from the story told by the Karewa deposits of the Kashmir valley that we come to know of the extreme youth of the Himalayas and that the western mountains of this chain have been uplifted from 5,000 to 8,000 feet since the advent of Man on earth.



TEXT-FIG. 4.—General section to show the disposition of the Palæozoic rock-systems of Kashmir.

(1) Lower Cambrian; (2) Silurian; (3) Muth quartzite (? Devonian); (4) and (5) Panjal Volcanic Series (Upper Carboniferous and Permian); (6) Upper Trias.

AN OUTLINE OF THE VEGETATION OF INDIA.

By

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Contents.

General.

While a knowledge of the geographical and climatal features of India is essential to any understanding of its Flora these features can only be touched briefly in such a short account of the vegetation as is here proposed. The term India as used herein excludes the now separated province of Burma, also Ceylon and the countries to the north-west, Afghanistan, Baluchistan, etc., although passing references will be made to features of the vegetation of these especially where such features indicate differences or invite comparisons or otherwise throw light on the vegetation of India proper. It is not intended that this account should present other than a somewhat distant bird's eye view of the extremely varied communities of plants extending throughout the country. For a closer view the visitor must have recourse to the works themselves on which this outline is based as well as to herbaria and to wide travel, but if it serves the purpose of indicating the range and content of the country, vegetatively treated, and brings into relief the variety and richness of its flora this is all that is intended.

It is based largely on a collation of all those works which preceded the publication of Hooker's *Flora of British India* as well, of course, as of this last, but it attempts to take in matters of more recent origin, work scattered throughout the various provincial and local floras and lists. It draws very freely from the account of the Botany of India published in the *Imperial Gazetteer*

the treatment in which is copied as the best means of reaching the object now desired, and the material of which it is hoped to sift and condense as well as to augment where information acquired since publication of the Gazetteer is likely to be of interest.

India probably presents a greater variety of meteorological conditions, actions and features than any area of similar size in the world. Rainfall, with which is associated the humidity of the atmosphere and which more than any other meteorological condition exercises an influence on vegetation, varies from some 450 inches in the hills of Assam to the north-east of the Bay of Bengal, and from some 350 inches in certain portions of the Western Ghats to as little as 3 inches per annum in Sind. During the south-west monsoon from June to September the air is super-saturated with moisture in the coastal districts and in the hills, while during the dry weather it may in certain districts be so dry as to defy the ordinary methods of calculation for humidity. In one season of the year the plains of India are the scene of the most wonderful and rapid growth of vegetation, a season of plenty for man and beast, in another they become a dreary brown sunburnt waste where the herbivore starves by the multitude and where it passes the understanding of man how any creature dependant on vegetation can come through the season. Such are the extremes presented by humidity, such the effects on vegetation and such the results.

Temperatures, which would seem to be of considerably less importance to plant life than water supply but whose effects as exemplified in the altitudinal range of Himalayan vegetation are yet appreciable show scarcely less extreme conditions than does humidity itself. From Greenland's icy mountains to India's coral strand has its counterpart for the Botanist in all conditions from her own barren icy mountains to the relatively mild green belt that characterizes her strands. And in the plains of Upper Sind, as in the Pab desert, can be studied a vegetation that suffers at one time of the year a temperature reaching 130 in the shade and at another conditions approaching those of the winter of Europe.

The physical features or topography of India is second in its importance to her plant life only to the influence of climate. Here again a variety is evident that few if any areas of similar size in the globe present. In the north extending from Assam to Kashmir and running in a general north-westerly direction lies the massive range of the Himalayas with a vegetation richer and more varied than that of any other part of India if not of the world. This is separated from Peninsular India proper by the Indo-Gangetic depression, a broad belt of country through which in the west the Indus and its tributaries drain in a south-westerly direction to the Arabian Sea, while at no great distance from the source of this system the Ganges takes its rise to drain the great fertile plains of North-East India comprising the United Provinces, Bihar and

Bengal. In this Indo-Gangetic depression are found the greatest extremes of conditions for plant life. From a wide sun scorched desert in the west where plant life can scarcely exist we pass by gradation to the ever green delta of the Ganges a thousand miles distant.

India south of the depression is characterized by a backbone of mountains in the west running parallel to the coast, at no great distance from the Sea; on the north by the Aravalli range and the rising uplands of Central India and Chota Nagpur and on the east by the range known as the Ghats. Roughly these bound and contain the great central plateau, itself intersected mainly from a westerly to an easterly direction by the water system of the Godavari and Krishna and minor streams draining into the Bay of Bengal. To the south of the peninsula the ghats taper off in the Nilgiris and Cardamom hills to gentle smooth rounded slopes of green uplands. Between the ghats and the Sea there is a comparatively narrow flat or gently sloping belt where, as in the west, the vegetation is tropical, in the east much more scanty except in the vicinity of the river mouths.

The whole of the truly peninsular part of India comes more or less under the influence of the trade winds carrying their moisture-laden burden. The moderating influence of proximity to the ocean tends to temperatures showing less variations; climates are more equable and there is much less seasonal variation in the vegetation than is to be found in the more extreme conditions away from the sea or out of the way of the main monsoon routes.

When the geographical extension of India is considered, when the number of degrees of latitude, temperate and tropical, it embraces is kept in mind, and when one recognizes it a land rising from the level of the sea to heights above the limits of vegetation, with torrid and arctic arid and humid conditions, the variety and wealth of its flora need occasion no surprise.

Of the elements of the flora of India, the Malayan is dominant. This undoubtedly arises from the fact that the barriers set by climate and by the high uplands and mountainous frontiers to the infiltration of plants from the north and north-west are absent from Malaya. The sea is a still more effective barrier so that the African and to a still higher degree the Australian and American elements are less well represented than the European and middle east floras. No fewer than 570 European genera figure in the Indian lists, many of them, however, represented by a single species; and the middle eastern element is certainly, as is to be expected, not less prominent. How far the European plant element in India may be considered as native is a subject of speculation, but the recent influx of American species taken with their marked tendency to spread makes it possible to suppose that modern transport has been an agent and that before the era of Indian botanical work a considerable European element had by this means managed to reach and establish itself

in this part of the world. It is curious that although the Tibetan and Siberian floras only reach India in the alpine regions of the Himalaya the Chinese and Japanese floras are strongly represented in its temperate belt.

An examination of the Flora of India reveals the outstanding peculiarity that not one of the families of flowering plants is peculiar to it; and if the genera common to India and some adjacent countries be excluded few endemic genera remain, and such of them as are endemic are local and with few exceptions are restricted to one or few species. When, therefore, the immense range of conditions that India presents for plant life be considered it is an enigma that its flora can yet be considered as merely an aggregation of several floral types.

The Australian element in the Indian flora is curiously represented by certain species of genera that are all but endemic in the southern continent, namely, *Baekia*, *Leptospermum*, *Melaleuca*, *Leucopogon*, *Stylidium*, *Helicia* and *Casuarina*. *Oxybaphus* of the Himalayas is otherwise a purely American genus. *Pyrularia edulis* is linked geographically to Java and North America and *Vogelia* to South Africa and Socotra. There are curiously no Myoporaceæ, Empetraceæ or Cistaceæ in India, and though the Lime, the Beach and the Chestnut extend from Europe to the Far East they avoid even the temperate belt of the Himalayas.

With the exception of the *Rhododendron* belt in the Himalayas the Pines of the north-west, bamboos locally in parts of Southern India and Burma and certain elements of the Xerophytic vegetation of the Indian desert, there are few assemblages of plants in India that characterize landscapes over wide areas. Palms in the lower areas of the peninsula, *Acacias* in many places, *Strobilanthes* as in the Nilgiris, *Dipterocarpus* as in the extreme east of our area and in Burma and Sal at the base of the Eastern Himalaya give a mark to the vegetation over considerable areas but they are far from taking the place of assemblages. They are at best conspicuous features of the landscape but not dominant. There is nothing for instance like the heaths of Britain or these and succulents in South Africa, the Eucalypti and Proteaceæ in Australia, the Cacti in America or the Aloes and Euphorbias of East Tropical and South Africa. The Prairies and Pampas of America have no corresponding assemblages here. The flora of the whole peninsula still strives, one member with another, and victory over wide areas to a gregarious species has yet to be established. We may even have to fix on certain plant immigrants of recent advent if we wish to illustrate the march of the struggle for supremacy. *Eichornea*, the water pest of Lower Bengal, now more than gives a distinctive feature to the landscape; *Lantana* is a widespread pest and *Croton sparsiflorus* shows signs of establishing itself to the exclusion of most else and in tracts of waste land. Of the same class but less objectionable than *Eichornea* are *Eupatorium odoratum*, *Ageratum*

conyzoides, *Mikania scandens*, *Argemone Mexicana*, *Suæda maritima*, *Opuntia Dillenii* and the lawn weed *Evolvulus nummularius* which is steadily increasing its hold. Quite a number of species of exotic *Oxalis* are now present amongst which *Oxalis corymbosa* tends to become a pest. The 'Flora advena' of India shows a marked number of species of American especially semi-tropical American origin. One naturally asks whether the opening of the Panama Canal has not had an influence on the floral elements that have within recent times established themselves here.

To leave the not truly Indian members and revert to groups of the indigenous flora we note that the Palms are less diverse in specific characteristics than they are further East or in the new world. The most conspicuous are the Talipot palms (*Corypha*) although not nearly so numerous as the Indian dates (*Phœnix*), or the Palmyras (*Borassus*) the Coconuts (*Cocos*) or the *Arecas* and *Livistonas*. These are mainly trees of the open plain or find themselves under cultivation. On the other hand, graceful erect or climbing palms with pinnate or fan shaped leaves frequent the humid evergreen forests where the Rattans (*Calami*) ascend the trees by their hooked spines and expose their feathery crowns to the light. More specialized and therefore more local, indeed locally dominant, are the all but stemless palms *Phœnix farinifera* of the Coromandal Coast, *Nannorhops Ritchieana* of North-Western India and *Phœnix paludosa* and *Nipa fruticans* of the Sunderbans. The last is estuarial and has a wide distribution. The Bamboos are nearly everywhere important. Well over a hundred species have been recognized by Gamble in his monograph of the group. They ascend from plains level to considerable elevations in most parts of India where the humidity allows of their development. They form, as elsewhere in the tropics, an important feature whether as clumps growing in the open or forming in association all but impenetrable jungle. They are the bugbear of the field botanist, for in addition to impeding his movement they shelter his most annoying enemies the ticks and the leeches. The taller kinds monopolize large areas in the hot lower regions, the smaller clothe mountain slopes up to 10,000 feet in the Himalayas. Of the endemic figs King has described 33 species and a multitude of others; they vary in size from small scandent and inconspicuous members like *F. scandens*, *F. macrocarpa*, *F. guttata*, *F. nigrescens* and *F. asperrima* to the spreading giants of the forest, *Ficus bengalensis*, *F. mysorensis* and *F. religiosa*.

Tree ferns of which there are comparatively few species and the Bananas of which more than are at present known seem likely to accrue to science, are comparatively local but yet conspicuous members of the vegetation.

The Conifers are almost entirely confined to the areas north of the great Indo-Gangetic divide. There are some 25 species of which a very few only are considered as not wild. Two species of

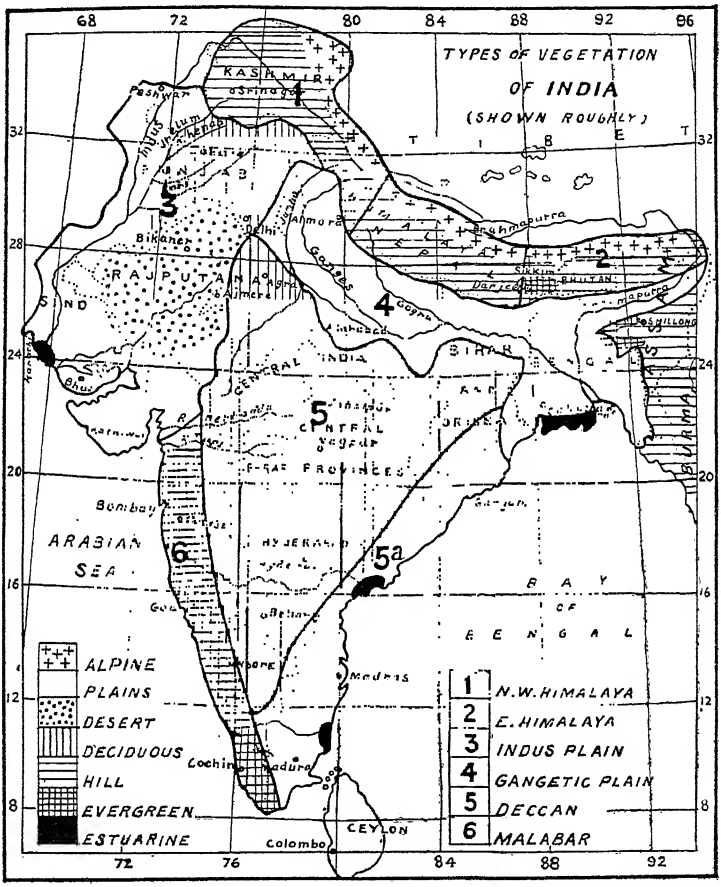
Juniper, a *Picea*, a *Taxus*, a *Tsuga* and a *Pinus* (*P. longifolia*) are common to the both ends of the range. *Agathis loranthifolia* and *Dacrydium elatum* are Malayan extensions and *Podocarpus neriifolia*, and *Pinus Merkusii* are more Malayan than Indian. *Juniperus communis* and *Taxus baccata* extend eastward from Europe, the latter to the Chino-Tibetan borderlands.

Types of Forest Vegetation of India.

The forest vegetation of India may be divided into five types; the evergreen, the deciduous, the dry, the hill and the tidal or littoral. The evergreen again is separable into two sections, that which comes under the influence of the main south-west monsoon and that, of the Carnatic, which depends on the much weaker winter or north-east rains. The former type occupies the west coast of the peninsula up to the ridge of the western mountain chain which cuts off the moisture laden sea winds from the Deccan and eastern portion of the peninsula. In the same way it is spread over the north-eastern part of the area with which we deal, and all the lower slopes of the Eastern Himalaya are characterized by it. It contains trees of many important families among which are specially noticeable the Dipterocarpaceæ, Guttiferæ, Annonaceæ, Meliaceæ, Burseraceæ, Sapotaceæ, Euphorbiaceæ and the Palmeæ. The evergreen forests provide in the main no exception to the rule of absence in India of a species dominant over a wide area; but some of its members, *e.g.*, Dipterocarps show nevertheless a tendency to the gregarious habit. They contain many species of great economic value and great size amongst which could be enumerated species of *Dipterocarpus*, *Hopea*, *Mesua*, *Calophyllum*, *Chickrassia*, *Cedrela*, *Dalbergia*, *Bischofia* and *Artocarpus*. Bamboos are plentiful and associated with them locally are to be found Teak, Rosewood and Ironwood. The Carnatic evergreens on the other hand are characterized by their comparatively smaller size and harder texture. Here we find the Ebony, species of *Mimusops*, the Jaman, the Neem and the Tamarind. The families Ebenaceæ, Sapotaceæ, Capparidaceæ, Rhamnaceæ and Myrtaceæ become prominent.

The deciduous type of forest occupies the larger part of the peninsula; it extends to Burma and is an important element in the Andamans. It is the most important from the forester's point of view containing as it does the main supplies of Teak (*Tectona*), Sal (*Shorea*) of the Sub-Himalayan tract, the Padauks and Redwoods (*Pterocarpus*), the Sandalwood (*Santalum*) of Mysore, Coimbatore and adjoining country and of Anjan (*Hardwickia*) the hardest and heaviest of Indian woods. Besides these, important species of the genera *Terminalia*, *Lagerstrœmia*, *Anogeissus*, *Soymida*, *Chloroxylon*, *Swietenia*, *Diospyros*, *Acacia*, *Albizzia* and others occur.

The dry forests are situated in Rajputana and the Punjab and spread over a large extent of native states. Towards the north and north-west they become richer and gradually blend into deciduous or alpine forests, whereas they get drier and drier towards



An outline map of India, showing Types of Forest Vegetation and Botanical Regions of India.

the west and south-west and disappear into the deserts on both sides of the lower Indus where the courses of perennial rivers alone are fringed by a belt of arboreous vegetation. The chief families represented in this region are the Leguminosæ, Capparidaceæ, Salvadoraceæ, Tamaricacæ and Rhamnaceæ, the most characteristic trees being the Jhand (*Prosopis spicigera*) and the various species of *Tamarix*, *Salvadora* and *Capparis*.

Hill forests are found within the Indian Empire along the whole of the Himalaya mountain chain from Assam to Hazara, and in the contiguous hill areas of Afghanistan, Baluchistan and Burma. In this belt the Coniferæ and Cupuliferæ find conditions for their development while other prominent families are the Sapindaceæ, Lauraceæ, Magnoliaceæ, Salicaceæ and Urticaceæ. Here flourish the Deodar (*Cedrus*), the pines (*Pinus longifolia*, *P. excelsa*, *khasya* and *Gerardiana*), the firs, *Abies Webbiana* ; the oaks include some six species while there are the Chestnut, Walnut, Maple, Elm, Ash, Birch, Poplar and Rhododendron.

The tidal or littoral forest type is situated along the moister part of the coast of India and especially in the deltas of its rivers. The prominent families of these forests are Rhizophoraceæ, Meliaceæ, Lythraceæ, Euphorbiaceæ and Sterculiaceæ and the chief timbers the Sundri, *Heritiera*, *Carapa*, *Avicennia*, *Sonneratia* and *Aegiceras*. The littoral forest is the home of the tidal palm Nipa, the leaves of which are so much used for roofing purposes and the distribution of which in similar conditions extends eastward over a wide area.

The shrubby and herbaceous vegetation will be touched on in examination of the floral regions which follows, but the freshwater flowering plants may be briefly referred to now. Of all these the Nymphæas with their allies *Nelumbium speciosum* and *Euryale ferox* are easily the most conspicuous. In the moister parts of India and especially in areas where the water level maintains a perennial supply of moisture for their existence in shallower water they are to be found in abundance and associated with these are to be found *Pistia stratiotes* and species of *Lemna*. Of recent times and developing with such rapidity as almost to crowd them out, is to be found the water pest *Eichornia*, referred to above as exotic. The Podostemonads are among the most remarkable of India's freshwater flora. They clothe rocks and stones in rapid streams with submerged spreading fronds resembling green lichens more than flowering plants. A recent examination of this type of flora shows no fewer than 160 flowering species as ' common water or marsh plants ' ; the carnivorous bladder worts and, very rarely, the Venus Fly trap of southern Europe are both present.

The largest family of flowering plants in India is Orchidaceæ, with some 1,700 species, but the attractiveness of the family has prompted a fuller examination of its members than has been the case with others, and it is not improbable that monographs of other groups will at least diminish the numerical supremacy of the Orchids. Next in order of dominance come the Leguminosæ, Gramineæ, Rubiaceæ, Euphorbiaceæ, Acanthaceæ, Compositæ, Cyperaceæ, Labiatæ and Urticaceæ. Of these all but Labiatæ and Compositæ are more tropical than temperate. The low place of the Compositæ, the world's richest family of flowering plants, is remarkable. In most countries it heads the list. Here it comes seventh,

and if the Himalaya in its temperate and alpine zones be excluded from our area,—and indeed these zones are floristically not truly Indian—the Compositæ would disappear altogether from the list of ten dominant families. Its members are, as elsewhere, mostly herbaceous, rarely shrubby or tree-like. They are very seldom—*Artemisia* is an exception—gregarious. Monocotyledons in the Indian flora are relatively important, there being one for every seven species of Dicotyledons in spite of the fact that the Gramineæ as a whole are relatively weak. The Aroideæ on the other hand are well represented as are also the Scitamineæ and the Dioscoreaceæ.

THE BOTANICAL REGIONS OF INDIA.

The area with which we deal is primarily divisible into three botanical areas: a Himalayan, an Eastern and a Western. The prominent characters of the three are—that the Himalayan area presents a rich tropical, temperate and alpine flora with forests of Conifers, Oaks, Rhododendrons and a profusion of Orchids; that the Eastern has no alpine flora, a very restricted temperate one, few Conifers, many Oaks and Palms and a great preponderance of Orchids; that the Western has only one Conifer, no Oaks, few Palms and comparatively few Orchids. Further the Himalayan Flora abounds in European and Siberian genera; the Eastern in Chinese and Malayan; the Western in European, Oriental and African.

Climatic and physical conditions, however, admit of a rough division of India into six botanical regions, and an examination of the floral features of these will end this account.

These regions are the Eastern and Western Himalayas, the Indus plain, the Gangetic plain, Malabar and the Deccan, the two last in a very extended sense.

The Eastern Himalaya

The Flora of the Eastern Himalaya is well represented in Sikkim, the area which is botanically best known. This is the most humid district in the whole range. It contains over 4,000 species of flowering plants belonging to some 160 families besides 250 ferns and their allies, of which 8 are tree ferns. The ten dominant families of plants in order of numerical importance are Orchidaceæ, Gramineæ, Leguminosæ, Compositæ, Cyperaceæ, Urticaceæ, Scrophulariaceæ, Rosaceæ, Rubiaceæ and Euphorbiaceæ. Its flora may be conveniently examined in three altitudinal zones, a tropical, a temperate and an alpine, but it should be understood that there is no hard and fast line of demarcation between these, plants of the tropical zone reaching into the temperate and *vice versa*, and so with the temperate and alpine zones. Monocotyledons stand to Dicotyledons as 1 to 2·5, and as we ascend, the number of species tends to decline as does the density of the vegetation. Thus in the lower and middle zones there are respectively four

and three times as many species as in the upper ; while the lower contains some 25% more than the middle.

The tropical zone which includes the gently rising plain at the foot of the hills is characterized above all else by its forests of Sal (*Shorea*) and by Leguminous trees (Plate I, bottom figure). There is a rich undergrowth of shrubs, coarse grasses and herbaceous plants belonging for the most part to the flora of the Gangetic Plain. Climbers abound from plains level upwards, there being representatives of all the chief climbing families—Ampelidaceæ, Cucurbitaceæ, Convolvulaceæ, Apocynaceæ, Asclepiadaceæ, Liliaceæ (*Smilax*), Dioscoreaceæ and Aroideæ, while herbaceous plants are well represented by Malvaceæ, Balsams, Orchids, Grasses, Aroids and especially in the rainy period by a profusion of Scitamineæ. Amongst shrubs the widespread prevalence of species of *Strobilanthes* in the forest is to be noted, whilst in clearings *Edgeworthia*, *Artemisia*, *Mæsa* and *Melastoma* seem to take their place.

There is a rich arboreal flora in this zone. The Magnolias reach profusion in its upper limit ; Annonaceæ, Meliaceæ, Leguminosæ, Combretaceæ, Euphorbiaceæ, Urticaceæ, Rubiaceæ and Sterculiaceæ are present throughout. The presence of *Quercus* and *Castanopsis* and of the pine (*P. longifolia*) in this belt distinguishes its floral type sharply from that of the plains, but species of *Ficus* and *Sterculea* carry the similarity to considerable levels. Some 18 species of Palms are to be found ; *Pandanus* is locally present to some height and Bamboos abound everywhere at the lower levels, there being some 12 different kinds.

In the temperate zone which may be said to extend from 6,000 to 11,000 feet the composition of the flora changes rapidly as we ascend. Numerical precedence is still retained by the Orchids, but a number of families which are of small importance at lower elevations here so greatly increase the number of their species as to prevail over the Leguminosæ, Euphorbiaceæ and Urticaceæ themselves. The Rosaceæ, Labiateæ, Ericaceæ and Umbelliferæ gradually reach importance in this zone to be themselves superseded at greater heights by more lowly if not less beautiful Primulas, Saxifragas and Crucifers. Of trees of the temperate zone the Magnolias—one species of which (*M. Campbellii*) formerly clothed the slopes round Darjeeling—are the most noteworthy ; but the belt is characterized by Oaks, Laurels, Maples, Birches, *Alder*, *Bucklandia*, *Pyrus* and Conifers including the Silver Fir, the Yew, a Spruce and the only deciduous Conifer in the Himalaya *Larix Griffithiana* and especially by its wonderful Rhododendrons. As the cultivation of tea does not extend much into it, the vegetation in this zone retains more of its natural aspect than is the case in large areas of the belt below.

The alpine zone sees the complete exclusion of Orchidaceæ from the list of chief families. The Compositæ now come into

their own, and associated with them in order of importance appear the Scrophulariaceæ, Primulaceæ, Saxifragaceæ and Coniferæ. The comparatively low position of the Sedges and Grasses is notable. One would have thought that the absence of canopy would have given these a chance at such heights. An explanation for the weakness may possibly lie in the depth of their root systems. But for a few Birches and Pyri that enter the alpine from the temperate zone trees would be entirely absent. Shrubby vegetation is represented by the Rhododendrons and Junipers and by species of *Ephedra*, *Berberis*, *Lonicera*, *Rosa* and *Cotoneaster*. An *Arenaria* which forms hard hemispheric or globose white balls is a characteristic feature of the landscape. But the most striking plants of the zone are species of *Meconopsis*, *Rheum*, *Primula*, *Tanacetum*, *Saussurea* and *Rhododendron*.

The Western Himalaya

Like the Eastern, the Western Himalayan botanical province can be divided into three roughly corresponding altitudinal zones, but the western province, considering its greatly extended breadth from south to north and therefore its much greater area, does not exhibit in respect of flora the degree of richness of the Eastern. The lower elevations of its south-eastern ranges display, however, general floral features not unlike those of the Eastern province. Taken as a whole the western area is botanically far better explored and yet the number of species in the whole of the known western area only equals the number in the comparatively small section taken as representative of the Eastern zone. In this province the Orchidaceous species recede from first place to seventh in the order of numerical importance. The cold loving and better drought resisting members of the families Gramineæ, Compositæ and Leguminosæ now head the list, while in comparison with the Eastern Himalaya the Labiates, Ranuncules and Crucifers gain markedly in importance. Bulbous plants predominate and Monocotyledons gain over Dicotyledons when comparison is made with the proportion in the East. The Vacciniaceæ, which represents a temperate or sub-alpine group of plants, curiously disappears in the West; but so also do the tropical Dilleniaceæ, Guttiferæ, Passifloraceæ, Myristicaceæ, Cycadaceæ, Burmanniaceæ and Pandanaceæ. Against their disappearance is to be placed the advent of such groups as the Resedaceæ, Moringeæ, Polimoniaceæ and Salvadoraceæ. An examination shows that of typically European elements there are twice as many in the western as in the eastern Himalaya, the presence of saline soil in the west accounting especially for the tremendous predominance in respect of Chenopods. Palms come down to six, including 3 species of *Phœnix*, against three times as many in the East. The occurrence in the North-West of the curious stemless *Nannorhops Ritchieana* has already been noted in references to the gregarious habit in the Indian Flora (Plate I, top figure). The tropical type of flora dies out rapidly as the extreme north-west portion of the province is

reached, but certain tropicals are yet found here that are absent from the Eastern province. Among these the true *Pistacia*, the Pomegranate and the Oleander are noteworthy. Bamboos practically disappear.

The temperate zone of the Western Himalaya is more hospitable than the Eastern to Conifers. All members present in the East, except the Larch, extend westward, but there get added forests of *Pinus longifolia*, *Abies Webbiana*, *Cupressus torulosa*, Junipers and *Pinus Gerardiana* (Plate II, bottom figure). Within temperate conditions oaks are more accommodating, the numbers in the east and the west more nearly equalling. *Quercus Ilex*, the Holm oak, fails to reach Sikkim but is present in the West.

Shrubs peculiar to the West are the Indian Bladder-nut, (*Staphylea*), the Lilac (*Syringa*), several kinds of Roses, the Mountain Ash, *Pyrus*, and the Hawthorn (*Cratægus*). But the chief difference lies in the greatly reduced number and importance of the Rhododendrons. Several Ranunculaceous herbs, unknown in the East, are here present together with species of *Aquilegia*, *Pæonia*, *Adoxa*, *Eriophorum* and many Grasses, Rushes and Carices. Balsams abound at all elevations in the temperate zone except the highest, the species being with few exceptions endemic. As is to be expected the decrease of rainfall as the Western Himalaya is reached results in a diminution of epiphytic vegetation, a fact emphasized by the relative preponderance in this zone of terrestrial, as against epiphytic, Orchids. Palms are confined to one species, *Trachycarpus Martiana*, and Bamboos to four dwarf gregarious.

The alpine zone abounds in Astragali and the prevalence of Artemisias, Saussureas, Tanacetums and others accounts for Compositæ taking first place here as it does in the corresponding zone of the Eastern Himalaya. Grasses and Legumes gain prominence as also curiously enough does the Gentians, a group one might think to predominate in the East with its Chinese element. Two conspicuous eastern alpines *Rheum nobile* and *Tanacetum gossypium* disappear although Arenarias carry on throughout the range at the higher elevations.

The Indus Plain

The Indus Plain province includes the Punjab, Sind and Rajputana west of the Aravalli range and Jumna river, Cutch and Gujarat. The forest flora of much of this region is fully described by Parker. Sal finds its extreme western limit in this province. The principal trees of the Indus Plain are *Bombax malabaricum*, *Sterculea urens*, *Moringa* spp. *Boswellia serrata*, *Odina wodier*, *Aegle marmelos*, *Pistacia integerrima*, *Prosopis spicigera*, *Acacia* spp. *Dichrostachys cinerea*, *Dalbergia* spp. *Mimosa* spp. *Anogeissus pendula*, *Cordia* spp. *Tamarix* and *salix*. Except, however, towards the lower levels of the Himalayas, on the slopes of the Aravallis and where irrigation allows of the development the forests are stunted and tend more to scrub. Saline tracts characterize the province over wide areas ; here

species of *Salsola* and the Arabic grass, *Sporobolus* thrive, elsewhere the odorous *Andropogon jwarancusa* and *A. nardus* and among trees *Acacia arabica*, *Tamarix articulata*, and *Butea frondosa* are said to stand the saline conditions well. Along the rivers *Tamarix dioica* is the commonest woody plant along with *Populus euphratica*, but *Acacia Farnesiana* is naturalized and *Dalbergia sissoo* is commonly planted. Compared with the adjoining Western Himalaya the flora is poor and is naturally adapted to the semi-desert conditions, for whether we proceed across the province in a south-west direction from the Himalaya to Sind or in a south-east direction from the Afghan border to western Rajputana vegetation rapidly diminishes, approaching extinction in the Indian desert. Irrigation in the Indus Plain province has greatly affected the natural flora. The chief families of plants are still those that take precedence in the Western Himalaya, the Gramineæ, Leguminosæ, Compositæ and Cyperaceæ heading the list in both provinces, but the number of species in the plain is only about a third of that in the Western Himalaya. Shrubby vegetation as is to be expected largely takes the place of trees and among the herbaceous there is a strong element of the annual type or of vegetation that can withstand prolonged periods of drought. The most conspicuous shrub is the Xerophytic *Euphorbia Royleana* but *Capparis*, *Zizyphus*, *Grewia*, *Balanites*, *Calotropis*, *Alhagi*, *Cassia*, *Dodonea* and *Calligonum* are genera represented and are all prevalent (Plate II, top figure). *Gossypium Stocksii*, the only indigenous cotton of the old world, is confined to Sind.

The deltaic vegetation of the Indus resembles that of the Sunderbans but is much poorer in species, one of the main elements in the East, *Nipa fruticans*, being absent in the West as is also *Phœnix paludosa*. The only Palms of the Indus Plain are the wide-spread *Phœnix sylvestris* and the local gregarious *Nannorhops Ritchieana* the presence of which is indicative of dry sandy conditions. Besides in Sind the latter finds conditions favourable for its development in the Salt Range. The hardy Bamboo, *Dendrocalamus strictus*, is the only natural representative of its class in the area. The whole area attracts the physiological botanist and the ecologist rather than the systematist.

The Gangetic Plain

The Gangetic Plain botanical province has through the influence of man in the course of untold generations lost much of its primeval appearance. It is agriculturally the richest part of India and is now to a very great extent given over to cultivation. With the exception of the Sunderban part the flora, therefore, is not now what it came from or what it would revert to if the hand of man were removed. There are records of its being covered at one time by vast forests of Sal which have now all but disappeared except on the slopes and at the base of its mountain boundaries. It is geologically of recent origin having been formed in the course of

ages by the silt of the Ganges and its tributaries which may at one time have linked with the Indus System. Botanically it is not a single province : it would, indeed, even when the sloping hill tracts to its sides are excluded and still more when they are included, be better to treat it as three provinces. There is the flora of the Upper Gangetic Plain, between which and those of the Indus Plain the middle Himalayas and the Deccan there are marked affinities, the flora of the middle plain represented by the vegetation of Bihar and Orissa and Western Bengal and the flora of the lower plain or deltaic area typified in the Sunderbans. As the province has been well explored and shows itself divisible into three botanical sections it will be well to treat it so. The Upper Gangetic Plain includes all that country drained by the Ganges and its north and south tributaries from the edge of the rising country north-west of Delhi to a roughly north-south line running through Benares. The indigenous vegetation in its western part is that of a dry country, the trees in the dry season being for the most part leafless and the grasses and other herbs burnt up ; but by far the greater part of the land to the eastward contrasts with that to the west in being under cultivation. The flora of the western extreme as indicated by such species as *Peganum harmala*, *Pluchea lanceolata* and *Tecoma undulata* is continuous with the dry districts of the Indus Plain. The principal forest is that of Ajmere characterized by *Anogeisus pendula* and by species of *Boswellia*, *Balsamodendron*, *Moringa*, *Rhus*, *Acacia* and *Prosopis*. The Bengal rose occurs and in the cold season the area is characterized by a herbaceous annual flora in which many English species are to be found. Bamboos, unless where planted and tended or on the borders of the hills, are almost absent, but the Date Palm locally over the area and a few species of Rattans in the submontane thickets represent the Palms. *Salvadora* characterizes the so-called Reh-lands impregnated with their alkalis. The absence of Guttiferæ from the area is noteworthy, but this is only one family of a list of absentees that are yet present in the districts north, south and west of the Upper Plain. Leguminosæ, Gramineæ, Cyperaceæ and Compositæ occur in order of prevalence. Savannah or grass lands sometimes of considerable extent occur and are dotted with trees like *Bombax malabaricum*, *Randia uliginosa*, *Butea frondosa* and *Zizyphus* sp. (Plate III, bottom figure). The Middle Gangetic Plain takes in all the country to the east of a north-south line through Benares and includes the plains of Assam. It is the evergreen country of India in which cultivation has *par excellence* affected the flora. A huge sea of waving rice fields extending as far as the eye can reach now best characterizes it. The villages are buried in groves of mango, jack fruit, betel nut, figs and palms, and amongst the herbaceous vegetation the Aroids both wild and cultivated are conspicuous. Broad tanks take the place of the wells of Upper India and in these the lotus Nymphæas and all the

pond vegetation referred to above is to be found. This type indeed probably best represents the original flora of the Middle to Lower Gangetic Plain for it has been least interfered with by the hand of man. In the eastern portion where the waters of the Ganges and Brahmaputra tend to overflow, the jhils or side canals and old river beds are characterized by a luxuriance of marsh grasses and Cyperaceæ, typified by tracts of *Saccharum spontaneum*. Among the trees many are introduced *Bombax*, *Polyalthia*, *Eriodendron* spp. and even such common species as *Poinciana regia* (the gold mohur) *Lagerstroemia flos-regina*, *Pterospermum acerifolium*, *Casuarina equisitifolia* and *Artocarpus integrifolia* are of this kind. In the drier districts the Babul, *Acacia arabica*, is a characteristic feature. For a full account of the Sunderbans flora which together with the flora of Sikkim, visitors are likely to have a chance of inspecting, a reference is invited to Prain's works. This flora is notable from the fact that, considering the limited area occupied, it contains more local species than does any other botanical area in India. This is to be ascribed to the peculiarity of its soils being saline and to its receiving a more than ordinary share of the south-west monsoon rains.

The Sunderbans.—The Sunderbans are clothed with a dense evergreen forest of trees and shrubs and constitute, therefore, an important forest division. Typical of the Mangrove forest which takes precedence are species of *Rhizophora*, *Carapa*, *Ceriops*, *Bruguiera*, *Sonneratia*, *Aegiceras*, and *Avicennia* (Plate IV, bottom figure). A remarkable character in this vegetation is the habit of several of the endemic species to send up from their subterranean roots a multitude of aerial root suckers which act as respiratory organs. In some places these may become so numerous that passage through the forest is difficult. They act like a small forest of spikes jutting out from the ground. Two Palms of the Sunderbans deserve special attention, *Nipa fruticans* and *Phoenix paludosa*. The former covers considerable areas in great stretches of the tidal regions both here and further east, a palm taking almost complete possession of the borders of the estuaries where the conditions are brackish but declining waters that tend to become fresh (Plate IV, top figure). Repeated attempts to introduce it to the relatively sweet water of the Royal Botanic Gardens at Sibpur have been made but it always dies out. *Phoenix paludosa*, on the other hand, thrives in the drier localities. In addition to the Mangrove type we have, however, many Sunderbans species common to inland Bengal, *e.g.*, *Pongamia glabra*, *Kleinhovia hospita*, *Agle marmelos*, *Odina wodier*, *Cordia myxa*, *Streblus asper*, and *Barringtonia acutangula* being representatives of trees common to both. With the Mangrove is mixed Typhaceæ, Gramineæ and Cyperaceæ. As in the rest of the Gangetic Plain province the families Leguminosæ, Gramineæ and Cyperaceæ still stand out as including the largest numbers of species, but here the Orchidaceæ, in contrast to the upper sections of the plain, begin to

creep up the list of dominant families. There are some 13 species, all, however, epiphytic, a sign of the increased humidity of the atmosphere. It is curious that while the grasses are plentiful no species of Bamboo has been able to accommodate itself to the wet saline conditions. Amongst the undershrubs two species of *Acanthus* are prominent with their light blue flowers and holly-like leaves.

Malabar

From the humid character of the Malabar climate its luxuriant vegetation might be inferred (Plate III, top figure). In verdure it resembles the eastern part of the Gangetic Plain and most deltaic regions, but it has loftier trees and more palms: the shores are skirted with Coconuts, and the villages surrounded with groves of Betel-nut palms and Talipots, while *Vateria indica*, a noble Dipterocarp tree, is abundantly planted in many parts. Cassia and Cardamoms flourish wild in the jungles and the fact that Pepper can be cultivated without the screens used in other parts of India to preserve the humidity, conveys an idea of how naturally moist the coast region is. It is impossible to demarcate the Malabar region in a botanical sense from the Deccan, for the mountains of the Ghats project sometimes far inland and carry a flora characteristic of the west well into an area that is geographically Deccan. It is one of the botanically richest areas in India. The mass of the flora is Malayan and identical with that of Ceylon, and many of the species are further common to Khasia and to the base of the Himalaya. Teak is abundant but Sandal wood occurs only in the east and dry flanks of the ghats. The Cupiliferæ and Coniferæ are wholly unknown in the west. The most distinctive characters of the Malabar flora, in contrast with that of the Deccan, are primarily the excessive content of Guttiferæ, Dipterocarpaceæ, Palmæ, and Bambuseæ and secondly the great prominence of the Malayan type represented by Sterculiaceæ, Anacardiaceæ, Meliaceæ, Myrtaceæ, Melastomaceæ, Scitamineæ, Orchidaceæ, Aroideæ and others. As the visitor may possibly wish to see the Nilgiris and as this range forms part of the mountainous backbone discussed under Malabar a few notes on it may be of interest. The ravines and shady slopes near the undulating summits are occupied by thickets of small trees and bushes like those of Ceylon and they are equally characteristic of similar situations in the Khasia mountains. These mountains form a noeud of the Western Ghats where they attain their greatest elevation of 8,760 feet. They rise precipitously from the west to extensive grassy downs and table lands seamed with densely wooded gorges locally termed "Sholas". The "Sholas" are filled with evergreen forest, some of the most conspicuous trees being *Michelia nilagirica*, *Ternstroemia japonica* and *Gordonia obtusa* and species of *Ilex*, *Meliosma*, *Microtropis*, *Euonymus*, *Photinia*, *Viburnum*, *Eugenia*, *Symplocos*, *Glochidion* and *Araliaceæ* and Lauraceæ are all present.

Of shrubs *Strobilanthes* take first place. It is from these that the mountains get their name, the expanses of their blue flowers

being responsible for the term Nilgiris. Next come species of *Eurya*, *Ligustrum* and *Vernonia*. Of climbers we have *Rosa Leschenaultiana*, *Jasminum brevilobum*, *Gardneria ovata*, *Gymnema hirsutum* and *Elæagnus latifolia*. Amongst conspicuous herbs the genus *Impatiens* is a notable feature while at lower elevations in the "Sholas" *Hydnocarpus alpina* and a *Rhododendron* and *Vaccinium* stand out. Bamboos are rarer at these heights than is the case at similar heights in the northern ranges, but a Ceylonese bamboo *Oxytenanthera Thwaitesii* is found and also an *Arundinaria*. An analysis of the floras of the Nilgiri and of the distant Khasia, Manipur and Naga hills shows a striking affinity between the two. This is the more remarkable that the floras of intervening ranges of mountains do not form satisfactory connecting links. Peat bogs, which are of the rarest occurrence in India, are found in depressions of the Nilgiri Hills towards their summits. The peat is composed, as elsewhere, of Grasses, Sedges, Mosses and Rushes and the bogs are the location of the curious Ceylonese *Hedyotis verticillata* besides of species of *Utricularia*, *Eriocaulon*, *Exacum* and *Commelyna*. An exotic element in the form of Australian gums, which are widely planted, must strike every visitor to the Nilgiris.

Deccan

The whole peninsula south of the Ganges Valley and east of the Malabar Ghats is characterized by a plateau of medium height from which rise in an west-east direction spurs from the Western Ghats and through which flow eastward a series of rivers the Godavari, Krishna and Cauvery and others draining into the Bay of Bengal. These rivers have eaten more or less broad sections out of the plateau and up these sections where cultivation has not disturbed the natural vegetation, is to be found a flora more characteristic of the Indian plains, especially the western, than of the Deccan in its true sense. The plateau terminates in the east in a lower range of hills, the Eastern Ghats, the flora of which is still mainly Deccan, but from here to the sea the land falls more or less abruptly into what may be called the Coromandal Subprovince with a flora distinct in important respects from that of the true Deccan. Over the Deccan province deciduous forests are the most conspicuous feature of the plateau and comparatively evergreen ones on the coasts and slopes with an eastern aspect. The Sal (*Shorea*) finds its natural southern limit near the Godavari, but the Teak (*Tectona*) occurs at intervals over the whole Deccan area. The Northern Deccan is floristically linked with the temperate to subtropical floras of the Eastern and Western Himalayas. Here are still to be found for instance species of *Thalictrum* and *Berberis* and it is moist enough for the epiphytic Orchids and for such species as *Lasianthus laurifolius*, *Pygium acuminatum*, *Dysoxylum procerum*, *Ardisia depressa*, *Bielschmiedia fugifolia* and *Cyclostemon assamicus*, species that show special affinity with the floras of the humid districts of Assam and Burma.

Of Deccan forest trees there are several hundred species, amongst which Sterculiaceæ, Meliaceæ, Leguminosæ, Combretaceæ, Bignoniaceæ and Urticaceæ are well represented. The Satin wood (*Chloroxylon*), *Chikrassia*, the Indian Red wood (*Soymida*), and the Toon (*Cedrela*) are all important, but the best known is probably the Odoriferous Sandal-wood forests of which are to be found in Mysore and adjoining districts. *Butea frondosa*, so common in the plains and uplands to the south of the Indo-Gangetic flat, and *Cochlospermum gossypium* both trees characteristic of areas with marked seasonal variations are common throughout, and the same seasonal characteristic is accentuated in the prevalence of such shrubby vegetation as *Capparis*, *Grewia*, *Flacourtia*, *Diospyros*, *Flueggia* and *Phyllanthus*.

The herbaceous vegetation has a negative distinction in the relative absence of epiphytic Orchids and of Scitamineæ, groups that demand shade or all but permanently humid conditions, but the common annuals or perennials of the Gangetic Plain extend southward into a great part of the Deccan and prominent in the herbaceous class are Acanthaceæ, Commelynaceæ, Gramineæ and Labiatæ. The chief Bamboos are the common *Bambusa arundinacea* and *Dendrocalamus strictus* and of Palms the commoner dates are *Phoenix sylvestris*, *P. acaulis* and *P. humilis*, the Tal or Tar *Borassus flabillifer* and some Calami.

Mysore, Carnatic and Coromandal.—The vegetation of Mysore, which comes within the use here made of the term Deccan, may possibly call for special remarks as this State may be visited. The vegetation here like that of the Carnatic further south is somewhat scanty. The table land is often barren and the hills at best covered with a low shrubby vegetation. But towards the west, where the influence of the monsoon is felt, the vegetation tends to be similar to that of the Western Ghats, the Malabar type, and considerable forests are therefore found. The steep slopes of the Eastern Ghats which come normally within the influence of the north-east monsoon are also densely wooded, species of *Dipterocarpus*, *Pterocarpus*, *Acacia*, *Butea*, *Lagerstroemia*, *Terminalia*, *Nauclea*, *Diospyros*, *Tectona* and *Santalum* predominating. Few palms are indigenous, except in the dense western forest, but all the commoner ones are found in cultivation. The black cotton soils, which prevail over large areas in the Deccan, are characterized by an assemblage of indigenous plants among which the following trees figure : *Capparis divaricata*, *Acacia arabica*, *Prosopis spicigera*, *Parkinsonia aculeata* and *Balanites Roxburghii*. Shrubs are *Cadaba indica*, *Zizyphus nummularia*, *Cassia auriculata*, *Calotropis procera*, and *Jatropha glandulifera* and herbs *Hibiscus trionum*, *Momordica cymbalaria* and *Cressa cretica*. The Coromandal Subprovince carries the Deccan type of flora to the sea. Mangroves occur in the estuaries. Elsewhere thickets of thorny evergreen and deciduous trees and shrubs abound, but at its southern end the influence of the north-east monsoon is

lost and this part is hot and dry. It is characterized by the umbrella shaped *Acacia planifrons* and by the best Indian Sennas (*Cassia*).

Towards the north tracts of Nuxvomica and of Ebony are now economically important and the sandy soils of the coast are characterized by the uprooted masses of *Spinifex squarrosus*, a grass distributed by the wind. One introduced plant, *Opuntia*, is now, it would seem, more under control than it used to be.

EXPLANATION OF PLATE I.

FIG. 1.—S.-E. of Boya Fort, Waziristan.

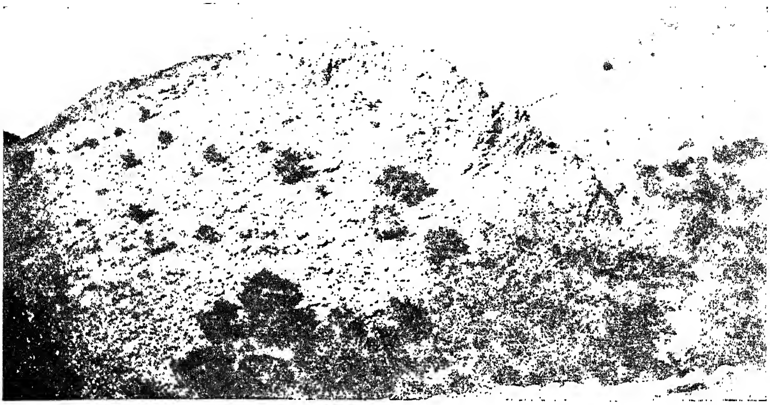
At the base *Nannorhops ritchieana* H. Wendl. Large trees of *Olea cuspidata* Wall. and *Monotheca buxifolia* Dcne. Small bushes of *Withania coagulans* Dunal.

Reproduced by courtesy of Bombay Nat. Hist. Society.

FIG. 2.—Portion of a *Sal* Forest, Darrang Forest Division, Assam.

Reproduced from *Indian Forester*, Vol. XLIII, (1917).

CALDER: *The Vegetation of India.* PLATE I.



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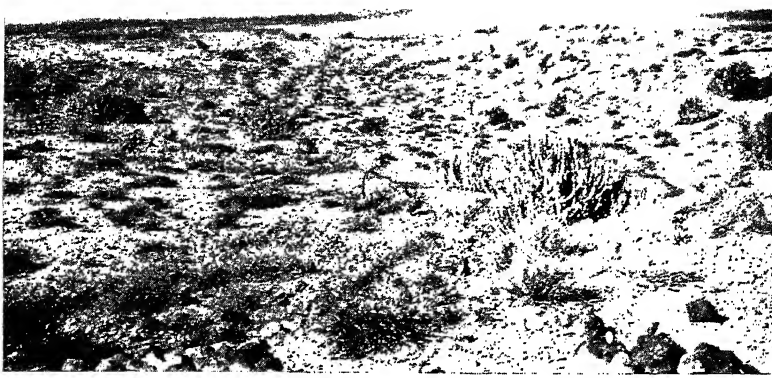
EXPLANATION OF PLATE II.

Fig. 1.—Typical desert vegetation in Sind.

Fig. 2.—Himalayan scenery at the edge of the tree line.
Both illustrations reproduced by courtesy of Bombay Nat. Hist. Society.



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EXPLANATION OF PLATE III.

FIG. 1.—Typical moist evergreen forest, Thattā Kād, Travancore.

Reproduced by courtesy of Bombay Nat. Hist. Society.

FIG. 2.—A portion of the bed of the Tons River below Jhajra. The sandy deposits on the banks of these large streams constitute an extensive savannah of *Saccharum Munja*.

Reproduced from *Indian Forest Memoirs*, Vol. I, (1911).

CALDER: *The Vegetation of India.* PLATE III.

1.

2.

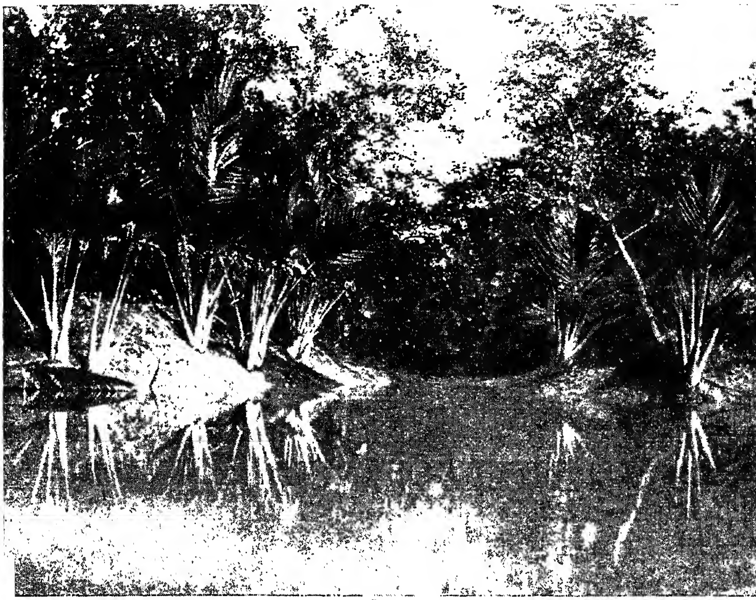
EXPLANATION OF PLATE IV.

FIG. 1.—A scene in the Sunderbunds at low tide.
A small river giving access to the interior of the jungle, and small palms growing out of the mud.

FIG. 2.—Malancha River during high tide, South Sunderbunds near the sea.

Both illustrations reproduced by courtesy of Bombay Nat. Hist. Society.

CALDER: *The Vegetation of India.* PLATE IV.



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2.

AN OUTLINE OF THE FAUNA OF INDIA.[1]

By

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CONTENTS.

INTRODUCTION.

The animal populations of India are infinitely more varied and colourful than its human populations with their innumerable tribes, castes, customs and languages. India is a land of contrasts with its varied physical and climatological features. It has some of the loftiest mountain ranges and low hills and plateaux, impenetrable evergreen forests and scrub-jungles, hill-streams with torrential falls over precipitous rocks, and broad and long placid rivers with their extensive deltaic and estuarine systems, rich alluvial plains stretching for hundreds of miles, and sandy wastes, deserts, and uncultivated open tracts of land, lakes, tanks and backwaters, and marshy, sandy or rocky coasts. The regular monsoons with their well-marked paths distribute their favours unequally so that there are regions of very heavy to moderate rainfall and of rainless

[1] In the preparation of this Outline the author has found the following works and journals of great help: 1. *Fauna of British India*, 2. *Imperial Gazetteer of India*, Vol. I, 3. *Journal of the Bombay Natural History Society*, 4. *Journal and Memoirs of the Royal Asiatic Society of Bengal*, 5. *Records* and *Memoirs of the Indian Museum*, 6. *Bulletins of the Madras Government Museum* and the *Madras Fisheries Department*, and 7. Alcock's '*A Naturalist in Indian Seas*'.

tracts. Parts of the country in the higher latitudes are subject to extremes of temperature, while those of the lower latitudes have a relatively more uniform climate. Elevations of the land in both the latitudes or the proximity of the sea tend to modify the severity of the climate to a considerable extent. The character and distribution of the animal communities in India are, therefore, to a large extent dependent on the physical and climatological features of the country. It must be remembered, however, that the past geological history of the Indian sub-continent and its adjacent land masses has played a considerable part in determining the character and distribution of the present fauna.

With a rich and varied fauna such as India has, any attempt to give a general sketch of the fauna characteristic of India as a whole would be attended with little success. The Indian subregion of the Oriental Region is overlapped by other zoological regions in its outlying parts resulting in the penetration of certain elements of the fauna from the latter regions into the outlying areas of the former. Thus the Eastern Himalayas, Assam and Burma which form the eastern portion of the Indian Empire have an Indo-Chinese and Malayan element in it, while the north-western part, including the W. Himalayas, the Punjab, Kashmir, W. Rajputana, Sind and Baluchistan, has a predominant Palæarctic element. The S.W. of India, also known as the Malabar Region, and S.W. Ceylon have a closely similar and characteristic fauna which is rich in individuals and endemic species.

The study of Zoology as a field science in India may be said to date back to the 17th and 18th centuries. To those interested in the historical aspect of field Zoology in India the admirable account of this subject given by Gravely (1922) would be valuable [1]. Within the last 25 years much of the field work done in India was officially sponsored by the Government of India, and unofficially by the Bombay Natural History Society among others. Expeditions such as those organized by the Cambridge University, the Yale University of the United States and others to study the field aspects of Zoology in India have been the exception rather than the rule. The Universities teaching Zoology in India are taking an increasing part in the exploration of local fauna thanks to the interest inculcated in post-graduate students for research work. But in recent years the progress of field Zoology under official auspices has suffered a set-back in India owing to the severe curtailment of Government grants to promote field work. Marine zoological survey work which started so well on the Royal Indian Marine Survey steamer 'Investigator' in the last quarter of the 19th century and flourished till 1925 has suffered similarly, first as a result of the world war, and lately as a result of the general financial stringency in the country since 1931.

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[1] *Proc. As. Soc. Bengal* (N.S.), XVII, pp. cxxxii–cxlvi (1921).

In the short space available for this Outline on field zoology it will be difficult to give an adequate account of both the Vertebrate and the Invertebrate fauna of the Indian Empire. The Birds amongst the former, and the Insects among the latter have attracted much attention because of their great variety and common occurrence in various situations all over the country, and the fact that the number of volumes dealing with these groups of animals in the *Fauna of British India* series which have hitherto been published far exceeds that of volumes devoted to all other groups of animals dealt with in the series is an indication of their wider appeal to naturalists and others. The depredations caused by wild animals, and insect and other pests to crops and human beings and the interest evinced in blood-sports by certain classes of people in India have stimulated the accumulation of much knowledge of the beasts of forest tracts and lesser jungles. A consideration of the relatively better known Vertebrate animals of the Indian Empire should more appropriately precede an account of the Invertebrate fauna which will be dealt with in relation to the types of environment common in the Empire and the animal communities characteristic of them. Although the work of the 'Investigator' (now of the Royal Indian Navy) in the Indian seas has revealed a wealth of interesting deep-water forms the account of the marine fauna in this outline is confined to that of the sea-beach between tide-marks and at a depth not exceeding one fathom. The fauna of the estuaries, lagoons and backwaters on the various Indian coasts are more or less of the same type with an admixture of animal forms that are of marine as well as brackishwater origins. The fauna of the fresh-water systems in the different parts of the Indian Empire includes species and genera which are of very wide distribution in the Oriental Region, but the few relict marine elements which are present in the rivers and lakes of India and Burma indicate the distribution of land and water in recent geological periods and the trend of migration of marine animals. The animal communities that have established themselves in caves, hill-streams, estuaries and desert tracts show considerable powers of adaptation which their congeners in other localities lack.

Mammalia.

Within the Indian Empire the Mammals are of very great diversity in form and habits. Certain groups of Mammals do not at all occur within Indian limits. Amongst these are the Duckbill and Spiny Ant-eater (Monotremata), and the pouched Mammals such as the Kangaroo and the Opossum (Marsupialia). The Camel, the Giraffe, the Zebra, and the Hippopotamus amongst the Ungulates, and the Seal and the Walrus amongst the Carnivora do not belong to the Indian fauna. The Mammals characteristic of the Indian Region are discussed below :—

Primates

Among the Primates the Monkeys are the best known in India, being represented by several species common in different parts of the country. The Simian Apes are represented by two species of Gibbons of the genus *Hylobates* which are found in the forests of Assam and Burma in large parties. The best known Monkeys are the long-tailed Bonnet Monkey (*Macaca radiata*) of South India and the short-tailed *Macaca mulatta* of Northern India, both of which are trained as performing monkeys by mountebanks. The Langurs or Hanuman Monkeys (*Pithecus entellus*) with longer limbs and tails are of legendary fame being connected with the story of the Hindu epic, Ramayana.

The Lemurs are not so well represented in India as in Madagascar. The Slender Loris (*Loris lydekkerianus*) living in the forests of South India and Ceylon, and the Slow Loris (*Nycticebus coucang*) living in the forests of Assam and Burma are the best known representatives of this group.

Carnivora

The terrestrial Carnivores of the Indian Empire include: (1) the Cat group, consisting of the cats, civets, mongooses, and hyaenas, (2) the Dog group, consisting of the dogs, jackals, wolves, and foxes, and (3) the Bear group, consisting of bears, badgers, martens, weasels and racoons. No true aquatic Carnivore occurs in the Indian Region.

The Cat-group : Large Cats.—The Indian Lions (*Panthera leo persica*) were, within historic times, found in North and Central India, but at the present day they occur only in the Gir Forest of Kathiawar peninsula covering an area of about 500 square miles of rugged undulating country of stunted trees, bamboo, and thorny shrubs and bushes. They are protected by game-laws within the Junagadh State of Kathiawar. The Tigers (*Panthera tigris*) live in India under varying environmental conditions such as the winter snows of the Himalayas up to an altitude of 10,000 ft., the humid ever-green forests, the dry open jungles, and the swamps consisting of grass and trees. They are absent from Ceylon where their place is taken by the Panthers. Of these latter (*Panthera pardus*) there are three races and varieties in the Indian Region differing in the colour and texture of the fur coat, *e.g.*, the Kashmir Panther (*Panthera panthera millardi*), the Sind Panther (*Panthera panthera sindica*) from the barren Kirtar hills of the Sind-Baluch frontier, and the Indian Panther (*Panthera panthera fusca*) whose range extends from the Himalayas to Cape Comorin and Ceylon. They thrive equally in the humid rain-swept forest and in the dry treeless tracts. The beautiful Snow-Leopard (*Uncia uncia*) is an inhabitant of the Himalayan ranges at altitudes varying from 6,000 to 18,000 feet above the sea level. The Cheetah or Hunting Leopard (*Acinonyx jubatus*) is almost extinct in the wild state, although it had once a wide range in the plains of North India. It is usually

found in low rugged country bordering the plains amongst rocks and boulders.

Small Cats.—The typical Cats (Felinæ) are represented in India by a number of small and medium-sized forms. The common Wild Cat of India, the Jungle Cat (*Felis chaus affinis*), is found in the drier parts of the Indian Empire where grass, scrub, or reeds abound, while the Desert Cat (*Felis ornata*) is found in the deserts and arid parts of N.W. India and in the eastern parts of the Central Province. The true Lynx (*Lynx lynx isabellina*) occurs in the Indus valley and Ladak, while the Caracal (*Lynx caracal*) or Siyah Gosh which is trained to hunt is common in the desert and scrub jungle of Sind, Cutch, and the drier parts of the Punjab, Rajputana, United Provinces, and Central India. The Leopard Cat (*Prionailurus bengalensis*) is an inhabitant of the ever-green or mixed forests of India and Burma while the Rusty-spotted Cat (*Prionailurus rubiginosus*) is common in the hill-forests and jungles of South India and Ceylon. The Fishing Cat (*Prionailurus viverrinus*) lives in heavy forests, scrub jungle of the Himalayan foot-hills, Ceylon and Burma, in grass swamps and reed-beds of rivers and tidal creeks of Bengal, United Provinces and Sind, and in the backwaters of the Malabar coast. The Marbled Cat (*Pardofelis marmorata*) is a forest-dweller of arboreal habit in the Eastern Himalayas, Assam and Burma. The Golden Cat (*Profelis temmincki*) has a similar range. The Sabre-toothed Clouded Leopard (*Neofelis nebulosa*) inhabits trees in the ever-green forests of Sikkim, Bhutan, Assam and Burma.

Civets.—The Large Indian Civet (*Viverra zibetha*) is found amongst bushes, thick grass or heavy scrub jungle in Nepal, Sikkim, North Bengal, Assam and Burma. The secretion of its perfume gland is reputed to have valuable medicinal and aphrodisiac properties. The other Civets are the Large Malabar Civet (*Moschothera civettina*) confined to Travancore and Cochin, the Burmese Civet (*Moschothera megaspila*) of South Burma, and the smaller Indian Civet (*Viverricula indica*) with several local races widely distributed in the Indian Empire. They live in holes underground or under rocks and bushes, and climb trees. The truly arboreal typical form of Palm Civet or Toddy Cat (*Paradoxurus hermaphroditus*), so called from its habit of drinking toddy tapped into pots on trees, is known from India south of the Narbada River and from Ceylon. It sometimes enters human dwellings. Other Palm Civets are the Brown Palm Civet (*Paradoxurus jerdoni*) from the hill-ranges of South India, and the Chinese Palm Civet (*Paguma larvata*) from the mountain forests of Kashmir, Punjab, Nepal, Assam, Burma and the Andamans, said to live in tree-holes. The Binturong or Bear Cat (*Arctictis binturong*) with a long prehensile tail used in climbing has much the same range as the preceding species and leads an arboreal life in dense forests. The Spotted Tiger Civet (*Prionodon pardicolor*) and the White-

eared Palm Civet (*Arctogalidia leucotis*) are also arboreal forms living in Assam, Sikkim, and Burma.

Mungooses.—There are several species of Mungoose living in forests, cultivated tracts, plantations, swamps, and the banks of rivers and streams. The common Indian Mungoose (*Herpestes edwardsi*) with various colour races and kept by itinerant snake-charmers and mountebanks is widely distributed in India. It lives in forests, in cultivated areas, taking shelter under rocks and boulders, in holes underground, in deserted Termite-mounds, and in human dwellings. The smaller Indian Mungoose (*Herpestes auropunctatus*) living in underground burrows is restricted to Northern India. The Ruddy Mungoose (*Herpestes smithii*) is restricted to forest areas in Central and Western India and Ceylon. The large Stripe-necked Mungoose (*Herpestes vitticollis*) is common in the hills of S.W. India and Ceylon and in the swamps and rice-fields of the Wynaad. The equally large Crab-eating Mungoose (*Herpestes urva*) lives on the banks of rivers and streams at low elevations in the S.E. Himalayas and in Assam and Burma.

Hyaena.—The Striped Hyaena (*Hyaena hyaena*) is an inhabitant of the drier parts of peninsular India among rocky hills and jungles. It does not occur in Ceylon or Burma.

The Dog-group.—The Dog-group consists of two species of wolves, one of jackal, two of wild dogs and five of foxes. A race of the European *Canis lupus* is found in the Punjab and Sind, while the smaller Indian Wolf, *Canis pallipes*, occurs throughout the Indian peninsula. Neither wolves nor foxes are known from Ceylon and Burma. The Indian Jackal (*Canis indicus*) is one of the commonest animals in India at dusk in the vicinity of towns and villages with its familiar long wailing howl and short yelps. Some, at any rate, of the domestic dogs are derived from the wolves and jackals, and the jackals are known to breed freely with dogs. The wild dogs (*Cuon*) are forest animals occurring in the well-wooded parts of India and Burma. The commonest Indian Fox, *Vulpes bengalensis*, which lives in all open parts of the country, ranges from the Himalayas to Cape Comorin and from Sind to Assam.

The Bear-group : Martens, Weasels and Otters.—The Indian Marten (*Martes flavigula*) is an inhabitant of the forests of the Himalayas and of the high hills of Burma. A dark form of this species occurs in the hills of South India. Weasels (*Mustela subhemachalana*) have a similar range. Amongst Badgers the best known is the Indian Ratel (*Mellivora indica*) found on river banks and in the hilly districts of peninsular India, but does not occur in Malabar, Ceylon and Lower Bengal. Of the Otters, the commonest is *Lutra lutra* living in rivers, tanks, and backwaters of India. The smaller Clawless Otter (*Aonyx*) inhabits the Himalayas and the eastern parts of the Empire, and the higher ranges of hills

in S. India. Others are tamed by the fishermen of the Sunderbans and Sind to drive fish into their nets.

Bears.—The Cat-bear or Himalayan Racoon (*Ailurus fulgens*) is met with in the forests of Nepal, Sikkim and the Eastern Himalayas. The Kashmir Brown or Isabelline Bear (*Ursus isabellinus*) occurs in the higher W. Himalayas above the tree-line. The Indian Sloth Bear (*Melursus ursinus*) inhabits bush and forest jungle, and hills, caves, and ravines of the Indian peninsula from the foot-hills of the Himalayas to Cape Comorin and Ceylon.

Insectivora

The Shrews are well represented in India, Burma and the Bay islands. The Tree-shrew (*Tupaia belangeri*) occurs in the tree-forests of Burma, Assam, and the lower Himalayas. True Hedgehogs (*Parœchinus micropus* and *Hemiechinus collaris*) occur in the sandy plains of North-West India. Of the Moles, *Talpa micrura* is common in the forests of Nepal, Sikkim, Assam and Burma. The best known of Indian shrews is the Grey Musk Rat (*Crocidura cœrulea*) closely associated with human habitations. Among the water shrews living on the banks of streams of the Himalayan, Sikkim and Burmese forests are *Chimarrogale himalayica* and *Nectogale sikkimensis*. The Flying Lemur (*Galeopterus peninsulœ*) occurs within Indian limits only in the forests of S. Tenasserim, Burma.

Chiroptera

Bats.—Of the Chiroptera or Bats, no less than 32 genera and 80 species have been recognized. We have space to mention only the most common and widely distributed forms in India such as the Indian Fruit-bat or Flying Fox (*Pteropus giganteus*) hanging in hundreds from branches of large trees, the insectivorous bats with nose-leaves such as *Rhinolophus affinis* of the hill-tracts of India, Burma and Ceylon, the Indian Vampire Bat (*Megaderma spasma*) living in caves and old buildings and feeding on other bats, frogs, and insects, the common Yellow Bat (*Scotophilus kuhli*) living in temples, sheds and old dilapidated buildings all over India, and the Painted Bat (*Kerivoula picta*) often found on plantain trees.

Rodentia

There are no less than 40 genera and 136 species of Rodents comprising squirrels, marmots, jerboas, rats and mice, porcupines and hares in the Indian Region. It is impossible to mention in this Outline more than a few of the commonest species occurring in it.

Squirrels.—The Flying-squirrel (*Petaurista oral*) lives in holes of trees. Of the ordinary Squirrels, *Ratufa indica* inhabits high trees in forests throughout peninsular India, and the common Striped Squirrel (*Funambulus palmarum*) lives in the more open cultivated parts, and in or near human habitations. The closely allied Marmots are inhabitants of the bleak regions of the higher Himalayas, and *Marmota himalayana* is the best known example.

Jerboas.—Within Indian limits the Jerboa (*Alactagulus indicus*) is known only from the plains south of Quetta at an elevation of

6,000 feet above the sea-level and from the N.W. Frontier where it lives in burrows. The Malabar Spiny Mouse (*Platacanthomys lasiurus*) lives in hollows of trees in Coorg, Anamalais, and the Malabar and Travancore hills.

Rats, Mice and Bandicoots.—The only Indian Gerbille is *Gerbillus gleadowi* from Sind and Thar deserts. Of the stout Bandicoots which are associated with human habitations and cultivated tracts and cause considerable damage to crops, etc., the best known are *Bandicota eliotana* and *B. malabarica*, the North and South Indian representatives respectively of the genus.

The Coarse-haired Bush-rat (*Golunda ellioti*) is also reputed to be destructive to coffee and other plantations in peninsular India. The common Indian Rat (*Rattus rattus*) is the widely distributed, probably indigenous, representative of the genus, while *R. decumanus* is the imported European Black Rat common in Indian ports. The genus *Mus* includes species of House-mice which are Palæarctic in distribution but have been helped by the human agencies of trade and commerce to spread themselves in the Oriental Region. The Long-tailed Tree-mouse (*Vandeleuria oleracea*) inhabits trees and shrubs and even houses in nearly all parts of Northern India.

Porcupines.—The best known Indian Porcupine (*Acanthion leucura*) lives in caves amongst rocks, in burrows on rocky hill-sides or river-banks all over India and Ceylon, while the Brush-tailed Porcupine (*Atherurus macrourus*) lives in the forests of Lower Burma.

Hares.—The Long-eared common North Indian Hare (*Lepus ruficaudatus*), and the black South Indian, *Lepus nigricollis*, live in waste lands amongst grass and bushes. The Mouse-hares (*Lagomys*) haunt rocky situations or pine forests of the higher ranges of the Himalayas.

Ungulata

The Ungulates constitute a very important group of animals in Indian economic life. The hoofed forms include the Elephant, Rhinoceros, Tapir, Horse, Cattle, Deer and the Pig which fall within four well-defined groups. They are ground dwellers, and barring a few, the majority of them are slender-limbed and fleet-footed in keeping with their habitat in open tracts where their enemies in pursuit are outdistanced by their speed of progression.

Even-toed Ungulates.—The Pecora or typical ruminants in India consist of wild and domestic cattle, sheep and goats, antelopes, gazelle and deer. Of these, all but the last are hollow-horned.

Cattle.—The Gaur or Indian Bison (*Bibos gaurus*) is essentially an inhabitant of the mountains and the larger hill-forests of India and Burma, while the Gyal (*Bibos frontalis*), a cross-breed between the bull Gaur and the domestic cattle, is found in the mountainous tracts of Assam and Burma (Plate V). The Banting or the Wild Ox

of Burma (*Bibos banteng birmanicus*) prefers the undulating or flat country or the lighter forests of Burma to hills. The Yak (*Pœphagus grunnieus*) does not strictly belong to the Indian fauna, being found only in the desolate mountains of the Tibetan plateau. The Indian Wild Buffalo (*Bubalis bubalis*) inhabits mainly the plains of the Ganges and Brahmaputra, the grass jungles of the Terai and Orissa and the eastern parts of Central Province.

Sheep and Goats.—The Wild Sheep or Oorial (*Ovis vignei*) has a varied habitat, from open valleys, hill-sides and grassy slopes in Ladak to rocky scrub-covered or barren hills of the Punjab, Sind, and Baluchistan. The great Tibetan Sheep (*Ovis ammon hodgsoni*), an inhabitant of the Himalayas, occasionally strays into Nepal, Kumaon, and Sikkim, while the Marcopolo's Sheep (*Ovis ammon poli*) lives in Hunza, Kashmir. The smooth, Round-horned Bharal (*Pseudovis nahoor*) lives in the rich grass lands between tree- and snow-line of the Himalayan ranges in Ladak, Nepal and Sikkim. The Sind Wild Goat (*Capra hircus blythi*) with its long scimitar-like horns lives in the barren hills of Baluchistan and W. Sind which are covered with stones and cactus, while the Markhor (*Capra falconeri*) with its spiral horns inhabits the most broken and precipitous country of the Suleman range and the mountains of Kashmir. The Asiatic Ibex (*Capra sibirica*) lives in the W. Himalayas above the tree-line. The Tahr, wild goat of the genus *Hemitragus*, inhabits the rocky forests of the southern slopes of the Himalayas and the open cliffs and precipitous slopes of the Western Ghats and Nilgiris living on grass growing between rocks or on adjacent grass downs. The Serow, Goral or Takin, also called the Goat-antelopes (Rupicaprinæ) because of the intermediate position they occupy between the goats and the antelopes, live in the thickly wooded parts of the Himalayas and in Burmese hills.

Antelopes.—The Antelopes (Antilopinæ) are ruminating Ungulates representing a transition between the oxen and the goats, and the only representative of this group in India is the Black Buck or Indian Antelope (*Antilope cervicapra*) with its beautiful spirally twisted horns which lives in scrub-covered or cultivated plains all over India except the Malabar coast. The Chinkara or Indian Gazelle (*Gazella bennetti*) is also an inhabitant of thin jungle or desert of the plains. The Nilgai or Blue Bull (*Boselaphus tragocamelus*) living in the open jungles or the hilly regions south of the Himalayas (except East Bengal, Assam and Malabar coast), and the four-horned Chousingha (*Tetraceros quadricornis*) with its peculiar glands on the hind false hoofs inhabiting the foot-hills of the Himalayas and the hill-tracts of peninsular India are representatives of Tragelaphine antelopes.

Deer.—The Deer are represented by several species. The Musk Deer (*Moschus moschiferous*) is a form intermediate between the antelopes and the deer, without horns but with strongly

developed canine teeth, gall-bladder, and a musk gland beneath the skin of the abdomen in the male, and lives above the pine zone of Kashmir, Nepal and Sikkim. The Muntjac, Rib-faced or Barking-deer (*Muntiacus muntijak*) is found all over India and Burma in more or less thick jungles. The Chital or spotted deer (*Axis axis*) is confined to India and Ceylon inhabiting the forests of Himalayan foot-hills and the more or less open jungles of Terai, Central Province and South India. The Hog-deer (*Hyelaphus porcinus*) lives in grass jungles of deltas, river-banks, and plains of N. India, in the scrub-jungle of Sind, and amongst the mangrove formations in Burma. The Indian Sambar Deer (*Rusa unicolor*) has a wide range in the Indian Empire and lives in forested hilly tracts not far from cultivation. The Swamp Deer or Barasingh (*Rucervus duvaucelli*) lives in marshes of the Terai and the Sunderbans and in the grassy plains of Central and United Provinces and of Assam. The Indian Chevrotain or Mouse-deer (*Moschiola meminna*) is a true ruminant without antlers, and, as its name indicates, is of very small size usually under 12 inches in height; it lives in grass-covered rocky hill-sides or in forests of Central and Southern India. There are two Burmese species, *Tragula canescens* and *T. kanchil.*

Boars and Pigs.—The Indian Wild Boar (*Sus cristatus*) is widely distributed in the Indian Empire and lives in grassy jungle tracts or in forests. The smaller Andaman Pig (*Sus andamanicus*) is peculiar to the forests of Andaman Islands, where it is seen in groups on the coastal fringe of the islands. The Pigmy Hog (*Porcula salvania*), only 12 inches high, is known only from the forests of the Himalayan foot-hills in Nepal, Sikkim, Bhutan and Assam.

Odd-toed Ungulates.—The Odd-toed Ungulates (Perissodactyla) are represented by the Horse, Rhinoceros, and Tapir. The horse family has within Indian limits only two species, the Kiang (*Equus kiang*) which lives in the open table-lands of Ladak, and Ghor-Khar or Indian Wild Ass (*Equus onager indicus*) which inhabits the plains and desert zones of Cutch and the areas west of the Indus.

Rhinoceroses.—The great Indian One-horned Rhinoceros (*Rhinoceros unicornis*), once widely distributed along the base of the Himalayas from Peshawar to Assam is at the present day confined to the part of Nepal east of the Gandak river and to Assam. It lives in swamps and grass-land and in the jungles of low hills. The smaller one-horned Javan Rhinoceros (*R. sondaicus*), an inhabitant of tree-forest up to an elevation of 7,000 feet, once abundant in Bengal, Assam and Burma, is probably at present confined to Malaya and Java. The Two-horned Rhinoceros (*R. sumatrensis*) was in former times common in the hill-forests of Assam and Burma, but is at the present time confined to certain districts of Burma.

Tapirs and Elephants.—The Tapir [*Tapirus* (*Acrocodia*)

indicus] is rare within Indian limits and occurs in the dense forests of South Tenasserim in Burma. The Indian Elephant (*Elephas maximus*) frequents hilly or undulating country covered with tall forests and thickets of bamboo all over the Indian R[illegible]cularly in Mysore and Burma. It does not, as a rule, breed in captivity, but a few instances of such breeding are known in Burma and in the Andamans.

Edentata

The Scaly Ant-eaters are represented in the Indian Empire by three species, *e.g.*, *Manis crassicaudata*, the Indian Pangolin, from the foot-hills of the Himalayas to Cape Comorin, *M. aurita*, the Chinese Pangolin from E. Himalayas, Assam and Burma, and *M. javanica*, the Malay Pangolin, from Bengal and Burma. All of them live in burrows dug by themselves or amongst rocks.

Cetacea

Of the truly aquatic mammals living within Indian limits there are very few species. The Gangetic Dolphin (*Platanista gangetica*) lives in the muddy waters of the rivers, Ganges, Brahmaputra and Indus, and of their tributaries and tidal creeks, but is not known to enter the sea. It has rudimentary eyes and is quite blind. The large Right Whale (*Balænoptera indica*) is sometimes reported as having been seen in the Bay of Bengal and Arabian sea by sailors. Several animals have, however, been stranded on the coasts of Burma, Ceylon, Malabar, Sind and Baluchistan. The Sperm-Whale or Cachelot (*Physeter macrocephalus*) is found generally in large herds in the open sea in the Bay of Bengal and round Ceylon. An individual of this species was stranded at Madras in 1890. The smaller Sperm-Whale (*Cogia breviceps*) is also reported to live in the Indian seas, and a young specimen was captured at Vizagapatam on the east coast. The Indian Pilot Whale (*Globicephalus indicus*) has been observed only once in brackish water of the Salt Lakes, Calcutta, in 1852. Of the porpoises, the Indian form (*Phocæna phocænoides*) occurs generally in tidal rivers such as the Hughli at Calcutta, and in shallow waters along the Indian coasts and the Bay Islands, while *Orcella brevirostris* occurs in the Bay of Bengal. *Orcella fluminalis* is found only in the Irrawady River, Burma. The Dolphins of the genera *Lagenorhynchus*, *Steno* and *Delphinus* have only occasionally been found along the coasts of India, Burma, Ceylon, and the Andaman and Nicobar islands.

Sirenia

The Dugongs, once fairly common, have become very rare along the Indian coasts. *Halicore dugong*, the Indian Sea-cow, has been observed on the coasts of Malabar, Gulf of Manaar, Andaman Islands and the Mergui Archipelago.

Aves.

The Birds of the Indian countryside, jungles and hill-tracts are of considerable interest from the point of view of their

variety and distribution. No less than 2,300 species and subspecies of Birds have been recognized. They belong to the many different habitats dealt with in connection with Mammals, Reptiles and Batrachia. Some species are resident in the Indian Region while others are visitors from the colder northern latitudes. The latter are therefore found in India during the winter months. Some of the most notable among the winter visitors are the Jackdaws, Rooks, Starlings, Martins, Cranes, Gulls, Pelicans, Swans, Terns, Curlews, etc. Some families of Birds include both resident and migratory species. Within the space available for the present Outline of the Indian fauna it is impossible to mention more than a few families of Birds which are of common occurrence in the Indian Region. The Passerine or Perching Birds constitute a vast assemblage of very closely interrelated species forming nearly a third of the total number of known species and subspecies.

Passeres.

Crows, Thrushes and Bulbuls, etc.—The Ravens, Crows, Rooks and Jackdaws are included in the Crow-family. The Jungle-crow (*Corvus coronoides*) and the ubiquitous House-crow (*C. splendens*) have a wide range from the Himalayas to Cape Comorin and Ceylon. The latter species is closely associated with human habitations in village, town or city. The Jackdaw and Rook are winter-visitors to N.W. India. The Indian Magpies (*Cissa*) are birds of beautiful plumage and red bills found in forests. In the plains the Tree-magpies (*Dendrocitta* and *Crypsirhina*) are common. The Titmouses (Paridæ) which are closely allied to the crows are found all over the Indian Empire. The Indian Parrot Bills and Suthoras (Paradaxornithidæ) are gregarious birds of the higher altitudes in E. Himalayas, Assam and Burma. The Nut-hatches (Sittidæ) are small slatey-blue birds which climb up stems of trees and surfaces of rocks and are mostly confined to the hills. The Thrushes and Babblers (Timaliidæ) are gregarious ground-feeders, the majority of which are Himalayan, Assamese and Burmese, but one species (*Pyctorhis sinensis*) has a wide distribution in India and Burma. The Bulbuls (Pycnonotidæ) are common all over India in gardens, cities and towns, but some are forest dwellers in the Himalayan and Burmese regions. Those with bright yellow or crimson tail coverts (*Pycnonotus*, *Otocampsa* and *Molpastes*) are some of the commonest Bulbuls of the plains. The Dippers (Cinclidæ) with special adaptation for a more or less aquatic life inhabit the rapid streams of high altitudes. The Shortwings, Chats, Forktails, Robins, true Thrushes with squamated plumage in the young inhabit the high hills, or the open, barren and cultivated tracts of India, Burma and Ceylon.

Fly-catchers, Drongos, etc.—The Fly-catchers (Muscicapidæ) are both resident and migratory birds. The beautiful Indian Paradise Fly Catcher (*Tersiphone paradisi*) frequents gardens, light forests, open country near villages and feeds entirely on the wing.

The Shrikes (Laniidæ), the Minivets (Pericrocotidæ), and the Drongos (Dicruridæ) are all closely allied families. The last-named (also called King-crows) are among the most common of Indian birds with glossy plumage and long forked tail and with musical voices. Like the Fly-catchers they also catch insects in the air. The Warblers (Sylviidæ) are small plain-plumaged birds of migratory or resident habit. They include the Tailor-birds (*Orthotomus*) well-known for their habit of sewing two leaves together with a piece of grass as a receptacle for their nest. The Yellow or Black Orioles (Oriolidæ) live in the plains as well as on the hills, the best known and widely distributed species being the Indian Golden Oriole (*Oriolus oriolus kundoo*). The Mainas of the families Eulabetidæ and Sturnidæ are also common throughout the Indian Region. The Indian Grackle (*Eulabes javana intermedia*) and the common Maina (*Acridotheres tristis tristis*) are familiar birds. The former is a favourite cage-bird in Assam and Burma because of its long life and extraordinary powers of mimicry of human voice. The latter is also used as a pet. The Weaver-birds (Ploceidæ) are also common in the Indian Region. Their curious flask- or retort-shaped grass nests on the leaves of date-palms, or on the branches of *Acacia* and other trees, or on bushes are a common enough feature of the country side. The Finches (Fringillidæ) are mostly migratory birds, but the Indian House-sparrow (*Passer domesticus*) with its three distinct races is the commonest species throughout the Indian Empire.

Swallows and Larks, etc.—The Martins and the true Swallows (Hirundinidæ) are both resident and migratory birds. Some of them are Himalayan while others are widely distributed. The migratory species when they visit India in winter from the northern latitudes spread gradually over the Indian peninsula and Ceylon. The Wagtails and Pipits (Motacillidæ) and the Larks (Alaudidæ) are widely distributed within Indian limits. The Bush and the Sky Larks are the best known, and the Desert Lark is found only in the Indus plain. The Indian Ruby Cheek (Chalcopariidæ) of low altitudes in the Terai, Sikkim, Assam and Bengal builds curious pear-shaped dome-like nests with the black fibres of certain ferns. The Sunbirds (Nectarinidæ) are of small size with a slender bill and a bright metallic-tinted plumage in the male. Some are widely distributed while others are restricted to hill-forests. The Flower-Peckers (Dicæidæ) are small forest birds frequenting the tops of high trees and found throughout the Indian region. The small beautifully coloured, broad- and flat-billed birds of Burma (Broadbills—Eurylaimidæ) live in small flocks among high trees.

Coraciiformes.

There are several species of non-migratory Wood-Peckers (Picidæ) living on the hills or in well-wooded country, but the two commonest species are the golden-backed *Brachypternus benghalensis* and the yellow-fronted pied *Leiopicus mahrattensis*. The Barbets (Capitonidæ) are well-

represented in India. Most of the species are grass-green in colour and frugivorous in habit. The best known Indian Barbet is the copper-smith bird, *Xantholœma hœmacephala*, whose distinctive metallic monotonous call may be heard in most Indian gardens.

Cuckoos and Parrots, etc.—To the Cuckoo family (Cuculidæ) belong the Indian Brain-fever Bird (*Heirococyx varius*) with its monotonous call-note in the hot season, the well-known mimic (*Surviculus*) of the common Black Drongo-shrike or 'King-Crow', and the Indian Koel (*Eudynamis scolopaceus*). The last named is widely distributed in India and Ceylon except in the very dry regions and is parasitic on the Corvidæ laying its eggs in the crow's nest. The Parrots or Paroquets (Psittacidæ) with long tails and green plumage are another common feature of the Indian Region. *Psittacula krameri*, the Rose-ringed Paroquet, is the commonest of Indian species inhabiting all open well-wooded country in the vicinity of human habitations. The Rollers or Blue Jays (Coraciidæ) are common throughout India in gardens, villages and on telegraph wires alongside railways. The King-fishers (Alcedinidæ) with black and white, green and blue, or violet and chestnut plumage are another common feature of Indian bird-life. The best known species are *Ceryle rudis* (Red King-fisher), *Alcedo atthis* (Common King-fisher), *Halcyon smyrnensis* (White-breasted King-fisher), and *Entomothera coromanda* (Ruddy King-fisher).

Hornbills, Hoopoes and Swifts.—The Hornbills (Bucerotidæ) are typical Indian birds. The female during incubation remains enclosed in a built-in hollow of a tree and is fed by the male. The smaller species, like *Lophoceros birostris* (common Grey Hornbill), prefer the open country to forests, while the larger species like *Dichoceros bicornis* (the Great Hornbill), *Hydrocissa malabarica* (the Pied Hornbill) and *Aceros nepalensis* (the Rufous-necked Hornbill) inhabit ever-green or deciduous forests. The Hoopoes are both migratory and resident birds, the Indian *Upupa epops orientalis* being found throughout India. The common Swifts, and those which make the well-known edible nests (*Micropus affinis*), the Palm Swift (*Tachornis batasiensis*), and the Edible Nest Swiftlet (*Collocalia unicolor*) are among the best known Indian species.

Owls.—The Owls, the Nightjars or Goat Suckers, and the Frog-mouths form a group of closely allied and widely distributed families. 35 species of owls are known from the Indian Region. The Indian Barn Owl (*Tyto alba javanica*), the Brown Fish Owl (*Ketupa zeylonensis*), the Great-horned Owl (*Bubo bubo bengalensis*), the various forms of Scops Owls (*Otus bakkamœna*), and the Spotted Owl (*Athene brama brama*) are among the best known forms.

Diurnal Birds of Prey.—The Diurnal Birds of Prey form a compact group of 3 families containing the Ospreys, Vultures, Falcons, Hawks, Kites, Eagles and Buzzards including no less than 74 species. On the sea-coasts

Accipitres

or on large inland waters of India the Osprey (*Pandion haliæetus*) is a winter visitor. Of the Vultures, the long-billed *Gyps indicus* and the white-backed *Pseudogyps bengalensis* occur practically throughout India and Burma. The Falcons include species with wide or restricted distribution some of which are of migratory habits. The best known of Indian Falcons and Eagles are *Falco peregrinus peregrinator* and *Aquila rapax vindhiana*. The Hawk-eagles are inhabitants of forests, while the Crested Serpent-eagle (*Spilornis cheela cheela*) is a soaring bird of the forests and plains. The white-bellied Sea-eagle(*Haliæetus leucogaster*) is common on the coasts of India, Ceylon and Burma and ascends tidal rivers to great distances inland. Amongst the widely distributed and well-known kites are the Brahminy kite (*Haliastur indus indus*) and the common Pariah kite (*Milvus migrans govinda*). The Indian Shikra (*Astur badius dussumieri*), one of the true Hawks, occurs throughout India in groves and orchards and is tamed for hunting Quails and other small game birds and even Crows and Herons. The Indian Crested Honey-buzzard (*Pernis ptilorhynchus ruficollis*) is not uncommon in the plains of India. It feeds on bees and their products, small frogs, reptiles, birds and mammals.

Columbæ and Pterocletes

Pigeons, Doves and Sand-grouse.—The Pigeons and Doves are common in all parts of the Indian Empire. The Green pigeons (Treroninæ) live in flocks in forests, and among trees in towns and villages. The large-sized Imperial Pigeons (Duculinæ) of dark-green coppery brown or grey plumage keep to the forest tracts of India, Burma and the Andamans. The Nicobar Pigeon (*Calœnas nicobarica nicobarica*) with long metallic hackles on the neck is an inhabitant of the Bay islands and is a ground-feeder. The true Pigeons (Columbinæ), some of which are winter visitors, include the Indian Blue Rock-pigeon (*Columba livia intermedia*), the Wood-pigeons (*C. palumbus*) and the Stock-pigeons (*C. œnas*). Some of the Doves are resident and others are migratory. The best known species with a wide distribution are the Rufous Turtle-dove, the Spotted-dove, and the Ring-dove of the genus *Streptopelia*. The Indian Emerald-dove (*Chalcophaps indica indica*) is a forest bird living on grains, fruit and termites. It is known to haunt salt-licks in Assam. The Sand-grouse which occupies an intermediate position between Pigeons and true Game-birds is found chiefly in open desert or dry broken country feeding on the ground and drinking water at definite hours of the morning or evening. The common Indian Sand-grouse (*Pterocles exustus erlangeri*) and the Painted Sand-grouse (*P. indicus*) are among the best known forms.

Gallinæ

Land Game-birds.—The true land Game-birds (Gallinæ) include the Pea- and Jungle-fowls, the Pheasants, Partridges, Quails and the Megapodes and are represented by 64 species. Pea-fowls are met with throughout India in a wild and domesticated state. The best known Pea-fowl

is *Pavo cristatus*. The Argus Pheasants (*Argusianus argus*) are confined to Tenasserim in S. Burma, while the Peacock Pheasants (*Polyplectron bicalcaratum*) are common in the forests of the Lower Himalayas, Assam and Burma. Of the true Jungle-fowls, the common Red Jungle-fowl (*Gallus bankiva murghi*), from which all domestic fowls are derived, is distributed as far south as Godavari River, while the Grey Jungle-fowl (*G. sonneratii*) is found in Central and South India, and *G. lafayettii* in Ceylon. In the Eastern Himalayas, Assam and Burma occurs a large variety of Pheasants, Quails, Koklas, Monals, and Partridges some of which have a wide range of distribution. The Megapodes (*Megapodius nicobariensis nicobariensis*) are inhabitants of the Nicobar Islands, and are remarkable for the fact that the young are born fully feathered and the eggs are deposited in huge mounds of sand and vegetable matter in the dense forests along the shores of these islands. The heat generated by the fermenting vegetable matter is sufficient to incubate the eggs.

Grallæ

Aquatic Game-birds.—The Rails, Crakes, Moorhens, and Coots (members of the family Rallidæ) live hidden amongst reeds, or in grassy swamps, weedy lakes, and small streams, and are consequently seldom seen. The White-breasted Water-hen (*Amaurornis phœnicurus phœnicurus*) and the Moor-hen (*Gallinula chloropus indicus*) are widely distributed throughout India and Burma. The Water-cocks or Kora (*Gallicrex cinerea*) are tamed as fighting birds by the people of Sylhet who hatch the eggs by tying them against their waists. The Masked Fin-foot (*Heliopais personata*) inhabits the swamps of the flooded forests of Assam and Burma. Other common birds of the swamps and lakes (in the plains and in the lower Himalayas up to 5,000 feet) with plenty of reeds, lilies and lotuses are the Bronze-winged Jacana (*Metopidius indicus*), and the Painted Snipe (*Rostratula benghalensis benghalensis*).

Cranes, Bustards and Floricans.—The true Cranes (Gruidae) are represented in India by six species of which the Demoiselle (*Anthropoides virgo*), the common Crane (*Grus grus lilfordi*), and the Siberian Crane (*Grus leucogeranus*) are winter visitors to Northern India. The Sarus Crane (*Antigone antigone antigone*) is a resident bird of the well-watered open plains.

Of the Bustards (Otididæ), the Great Indian Bustard (*Choriotis nigriceps*) haunts the plains of N.W. India and Deccan, while the Floricans (*Sypheotides indica* and *Houbaropsis bengalensis*) are met with in Peninsular India and in the plains of the Ganges and Brahmaputra respectively.

Charadriiformes

Plovers.—The Stone Plovers, Sand Plovers, Crab Plovers form a small group of birds of more or less similar habits. The Indian Stone Plover (*Burhinus œdicnemus indicus*) frequents arid country and sandy beds of rivers all over the Indian Empire. Some Stone Plovers (*Esacus,*

Orthorhamphus) haunt the sandy coasts along the Bay of Bengal, Ceylon and the Andaman islands. The Indian Courser (*Cursorius coromandelicus*) is an inhabitant of the more open and desert portions of India, scrub or grassy country, cultivated or waste land, while the Jerdon's Plover (*Rhinoptilus bitorquatus*) has a restricted distribution in the forest regions between the Godavari River and Madras. The Sand Plover (*Glareola lactea*) frequents stretches of shingle and sand of the larger rivers of India, while the Crab Plover (*Dromas ardeola*) is locally distributed in the Bay Islands and Mergui Archipelago.

The Charadriid Plovers, and the Curlews, Woodcocks, Snipes and Sand-Pipers (Scolopacidæ) include a large number of forms which are migratory and straggle down in winter as far south as Ceylon. The Great Sand-Piper (*Tringa ochrophus*) is known as the Snippet in India. Among the common snipes of India are the Fantail (*Capella gallinago*) the Pintail (*C. stenura*), the Wood-snipe (*C. nemoricola*) and the Eastern Solitary Snipe (*C. solitaria*). The last two are resident in the lower Himalayas, Assam and Burma. *C. nemoricola* extends to the hills of South India during winter.

Gulls and other Water-birds.—There are large numbers of Water-birds such as Gulls, Terns, and Skimmers many of which are winter-visitors to India straggling far inland to large areas of water such as rivers and lakes. Amongst the commonest of these are the Black-headed or Laughing Gull (*Larus ridibundus*, and the Yellow-Legged Herring Gull (*L. argentatus*), the Indian River Tern (*Sterna aurantia*) which keeps to the larger Indian rivers, the Black-bellied Tern (*S. melanogaster*) which frequents large lakes, swamps and rice-fields, and the Indian Skimmer (*Rhyncops albicollis*) living on the surface organisms such as small Crustacea, Fish, etc., in the larger rivers of India and Burma.

Steganopodes and Turbinares

Pelicans.—Amongst the Pelicans (Pelecanidæ), the eastern White or Rosy Pelican (*Pelecanus onocrocotalus roseus*) wintering in Northern India, and the Spotted-billed Pelican (*Pelecanus philippensis*) breeding in winter in South India, Ceylon and Burma, are common.

Cormorants and Snake-birds are inhabitants of freshwater areas all over the Indian Empire, but the former may often be seen fishing in the mangrove swamps and the sea. The Little Cormorant (*Phalacrocorax niger*) breeds in lakes and swamps during the monsoon. The Snake-bird (*Anhinga melanogaster*) is entirely a freshwater bird throughout the Indian Region.

Oceanic Birds.—The Gannets or Boobies (Sulidæ), black or brown birds of large size, inhabiting the open sea are casual visitors to the shores of India. The closely allied Tropic or Bosun Birds (Phæthonidæ) are oceanic birds following ships for many miles out at sea and visiting the coasts only for breeding purposes. The Frigate Birds (Fregatidæ) and the Petrels (Procellariidæ) are also

oceanic species recorded from the islands of the Indian Ocean, and from Ceylon.

Herodiones and Phœnicopteri

Storks, Herons, etc.—The Spoonbills, Ibises, Storks, and Herons constitute an important element in the bird life of India. The Spoonbills (Plataleidæ) have a range extending from Sind to Bengal and Ceylon. Within the Indian limits the Ibises (Ibididæ) inhabit rivers, lakes and swamps, and open dry cultivated country, and avoid deserts or the wettest regions of Bengal, Assam and Burma. The Storks (Ciconiidæ) include winter-visitors and resident birds. The common White-necked Stork (*Dissoura episcopa episcopa*) and the curious Open-bill (*Anastomus oscitans*) are among the resident species. The commonest of the Herons and Egrets are the Grey Heron (*Ardea cinerea cinerea*), the Purple Heron (*A. purpurea manillensis*), the White Egret (*Egretta alba, E. intermedia* and *E. garzetta*), and the Cattle Egret (*Bubulcus ibis coromandus*). The Reef-Heron (*Demiegretta sacra* and *D. asha*) are coastal or insular birds found on the coasts of Burma, Andamans, Ceylon, Laccadives, Sind and Mekran. The Indian Pond Heron (*Ardeola grayii*) is one of the commonest and best known birds of India, grayish-brown when sitting and white in flight. The Night Heron (*Nycticorax nycticorax*) is a truly nocturnal bird living in the deep shade of trees by day and flying at dusk to the feeding grounds near water. The Bitterns are crepuscular in habits and hide in long grass and reeds. The Chestnut Bittern (*Ixobrychus cinnamomeus*) breeds on the west coast of India and is a common resident of Bengal and Assam. The Flamingo (*Phœnicopterus ruber antiquorum*) is found as far down as Ceylon and east to Assam on the shores of lakes, and sea-coasts, and breeds in the Runn of Cutch.

Anseres and Pygopodes

Swans, Ducks and Teals, etc.—The Swans (Anatidæ) are rare in India. The Mute Swan (*Cygnus olor*) and Whooper (*Cygnus cygnus*) have been recorded on a few occasions in N.W. India.

Among the Ducks which breed in tropical India are the widely distributed Comb-duck or Nukhta (*Sarkidiornis melanotus*) and the Pink-head Duck (*Rhodonessa caryophyllacea*). The Mandarin Duck (*Aix galericulata*) is an extremely rare visitor to Assam. Of the true Geese (Anserinæ) only a few visit N. India and N. Burma during winter, such as the Gray Lag (*Anser anser*) migrating as far south as Bombay and the Chilka Lake and the Bar-headed Goose (*Anser indicus*) which extends down to Deccan and Mysore.

The Teals, Sheldrakes, Mallards, Gray-ducks and Shovellers are mostly migratory. The common Whistling Teals (*Dendrocygna javanica* and *D. fulva*) are permanent residents where swamps and lakes abound. The Brahminy Duck (*Casarca ferruginea*) prefers the larger rivers to lakes and ponds. The Spot-bill (*Anas pœcilorhyncha*) is resident throughout India and Ceylon. The Andaman Teal

(*Nettion albogulare*) is peculiar to the Andaman and Cocos group of islands and inhabits freshwater swamps and tidal creeks. The White-eyed Pochard (*Nyroca rufa rufa*) is one of the commonest of Indian Ducks occurring as far south as Mysore and Madras and is an expert diver. The Smew (*Mergellus albellus*) is a regular visitor to N. India and lives in clear rapid streams. The Eastern Goosander (*Mergus merganser orientalis*) visits the foot-hills of the Eastern Himalayas, and chooses swiftly flowing rivers or torrents, but is equally at home in clear lakes and ponds. The Grebes (Podicepidæ) are expert divers. The Great Crested Grebe (*Podiceps cristatus cristatus*) occurs only in N. India in marshes and lakes and in the sea, while the Indian Little Grebe (*P. ruficollis capensis*) is common all over the Indian Empire.

Reptilia.

In the Indian Empire this group is well-represented by a variety of forms of aquatic, semi-aquatic, terrestrial, and arboreal habits. The curious lizard-like Tuatara, the Alligators, the Iguanas, the Snake-like Amphisbænian Lizards, the Giant Land Tortoises, and the Rattle-snakes and Boas do not occur in this region, although the nearest relatives of all but the first are known from the Empire.

Crocodilia

Crocodiles.—There are only 3 species of Crocodiles in the Indian Region. The Gharial (*Gavialis gangeticus*) the sole living representative of the genus, occurs in the larger rivers of N. India, *e.g.*, the Indus, Ganges, Brahmaputra and Mahanadi living chiefly on fish, birds, and small mammals such as goats and dogs. Occasionally it may attack man. It has the habit of floating at the surface of water with only the eyes and the tip of the snout above water. The estuarine Crocodile (*Crocodilus porosus*) inhabits the coasts of India from Cochin to Ceylon, Bengal and Burma frequenting the deltaic tract of rivers and the backwaters, and enters the sea for several miles from the coasts. It grows to big sizes (over 20 feet long) living on fish, turtles, birds, crabs and even insects, and attacks man. The Mugger or Broad-snouted Marsh Crocodile (*Crocodilus palustris*) lives in freshwater swamps, tanks and rivers throughout the Indian peninsula and Ceylon, and in Baluchistan, Nepal, and in the Brahmaputra river. In the dry season it buries itself in mud to æstivate. It feeds chiefly on fish and birds, but occasionally attacks human beings.

Chelonia

Tortoises and Turtles.—The Tortoises and Turtles are represented by several genera and species. Of the latter, the Leathery Turtle (*Dermochelys coriacea*), the largest of all marine Chelonians, is found only on the coasts of Ceylon and Travancore, while the Green or Edible Turtle (*Chelonia mydas*) is particularly common around the Andaman Islands. The Hawksbill Turtle (*Eretmochelys imbricata*) which provides the

tortoise-shell of commerce is generally distributed in Indian and Indo-Chinese waters, but is not so common as the Green Turtle. The Logger-head Turtle (*Caretta caretta olivacea*) is abundant on the coasts of the Andaman Islands and Ceylon. The freshwater Tortoises (Emydidæ) are represented by no less than 33 species belonging to 15 genera. Several of these are confined to Burma and the Indo-Chinese sub-region. Among these may be mentioned *Geomyda trijuga* with a wide distribution in S. India, Bombay, Bengal, Burma, Ceylon and the Maldive Islands, *Geoclemys hamiltoni* of N. India, *Hardella thurgi* of the rivers Ganges and Brahmaputra, *Kachuga tectum* of the three great rivers of N. India, *Kachuga trivittata* of the Irrawady and Salween river systems, and *Batagur baska* of the estuaries, deep-rivers, and canals of Bengal and Burma. The commonest of the Freshwater and Mud Turtles of the family Trionychidæ are *Lissemys punctata*, *Chitra indica*, *Trionyx gangeticus*, *T. leithi* and *T. hurum*. The land Tortoises (Testudinidæ) are represented by the single genus *Testudo*. *T. elegans* is the commonest South and Central Indian species with the closely allied *T. travancorica* confined to the hills of Travancore. *Testudo emys*, the largest of Asiatic species, lives in the hilly districts of Assam and Burma.

Lacertilia

Gecko Lizards.—The Lizard-group includes a large number (248) of species occurring within the Indian limits, and consists of Geckoes, Chameleons, Skinks, etc. The Geckoes are found everywhere in the plains or at low altitudes except in thick jungle or in water. Some of them are closely associated with human habitations, some are found in deserts hiding under stones and in crevices of rocks, while others live in tree-holes or in cracks under the bark. They feed chiefly on insects. The commonest species are those of the genera *Gymnodactylus* of wide distribution, *Cnemaspis* from the hilly regions of S. India and Ceylon, and *Hemidactylus* with very wide distribution in all parts of the Empire. *Hemidactylus brooki* is the commonest House-gecko in India. The Tuck-too or Tuk-Kaa (*Gekko gecko*) of North-Eastern India and the Andaman Islands are large lizards living chiefly on insects but occasionally attacking larger animals such as other lizards, mice, small birds and even snakes. The parachuted *Ptychozoon kuhlii* of the Nicobars is reputed to fly from one tree trunk to another. The Green Lizard (*Phelsuma andamanense*) with red or orange markings and red tongue is a common inhabitant of the Andaman Islands on trees and in human dwellings. The Fat-tailed Lizard (*Eublepharis macularius*), an inhabitant of desert areas found in N.W. India, lives on other lizards, crickets and other insects, spiders and scorpions.

Ground and Flying Lizards.—The Agamid lizards include species which live on the ground as well as on trees in forests. The Flying Lizard (*Draco*), the so-called ‘ Blood-sucker ’ (*Calotes*), the Skinks, the Monitors, and the Chameleons belong to this family.

One species of Flying Lizard (*Draco dussumieri*) is found only in S. India, while the others, *D. maculatus*, *D. tæniopterus*, *D. blanfordi* and *D. norvilli* are not found west of Assam. Another common lizard of the drier and open districts of India and Ceylon is *Sitana ponticeriana*. Several species of *Calotes* are known, but the commonest species on the plains and hills of India and Ceylon is *Calotes versicolor*. The lizards of the genus *Agama* are found chiefly in the rocky country of North-West India, and feed on vegetable matter and insects. They hibernate during the cold season. The lizards of the genus *Uromastix* live in holes in the ground made by themselves in arid tracts. The Spiny-tailed Lizard (*U. hardwickii*) of N.W. India inhabits sandy tracts where vegetation is scanty and feeds on grass, flowers and fruit. It hibernates in its burrows during the cold weather.

Chameleons.—The Chameleons have their home in Madagascar and Africa, but in the wooded districts of peninsular India and in the dry zone of Ceylon they are represented by one species, *Chameleon zeylanicus*. They have the power of independent movement of the eyes, and an extremely extensible cylindrical sticky tongue, and can change their colour at will.

Skinks.—The very numerous species of the skink family (Scincidæ) include forms which live in damp places near rocky streams (the viviparous *Tropidophorus*), forms that live near the sea-shore (*Mabuya bibronis*), and forms that live in burrows and are crepuscular or nocturnal (*Barkudia insularis*) . Of the commoner Skinks are *Mabuya carinata* of peninsular India, *M. beddomii* of S. India, and *M. dissimilis* of N. India. The largest of the Indian Skinks (*M. tytleri*) is peculiar to the Andaman Islands. *Dasia olivacea* of Tenasserim and the Andaman and Nicobar Islands is arboreal in habit. Other common forms are *Lygosoma indicum* of the E. Himalayas, Assam and Burma, *L. dussumieri* of S.W. India, *L. taprobanense* of Ceylon, *Leiolopisma himalayanum* of the sub-Himalayan tract up to elevations of 12,000 feet, and *Riopa punctata* widely distributed in the hilly parts of India and Ceylon. The 'Sand-fish' (*Ophiomorus tridactylus*) which burrows in sand is common in the desert and shady parts of India. Another similar form which burrows in loose earth is *Barkudia insularis* of the Chilka Lake on the east coast of India. The degenerate Ceylon Skinks of the genus *Nessia* live in earth or decaying vegetation or under stones, and feed on worms. The snake-like, externally limbless Burmese Glass-snake (*Ophisaurus gracilis*) is common in the Himalayas, Assam and Burma.

Monitor Lizards.—There are six species of Monitors (*Varanus*) within Indian limits. The Desert Monitor (*Varanus griseus*) inhabits sandy places in N.W. and Central India where vegetation is scanty. *Varanus monitor*, the common Indian Monitor occurs throughout India, Burma and Ceylon while the common Water

Monitor (*V. salvator*) frequents rivers, estuaries and sea-coasts of Bengal, Burma and Ceylon. There is a considerable trade in lizard skins in India.

Ophidia

Snakes.—The Snakes constitute a large and important element in the Reptilian fauna of India, and there is no known family of living snakes which is not represented in this country. The large number of deaths amongst domestic animals and human beings caused by the bite of poisonous species of snakes has focussed much attention on this group. Zoologists and medical men have attempted to provide intelligible guides to the lay people to distinguish at sight poisonous from non-poisonous snakes. Amongst the commonest species met with in the Indian Empire may be mentioned the Carpet-snake (*Lycodon aulicus*), the Rat-snake or Dhaman (*Ptyas mucosus*), the Grass- and the Water-snakes (*Rhabdophis stolatus* and *Nerodia piscator*), the Tree or Whip-snake (*Dryophis mycterizans*), the Cobra (*Naia naia*), the Krait (*Bungarus candidus*) and the deadly Russel's Viper (*Vipera russelli*). The Sea-snakes (Hydrophinæ) with a strong, compressed, oar-shaped tail are also common on the Indian coasts, the most widely distributed being *Hydrus platurus*, and *Enhydrina valakadien*. The latter is known to be the most poisonous of all Indian snakes. There are other snakes not so well-known but which, nevertheless, deserve mention. The burrowing 'Earth-snakes' (Uropeltidæ) are peculiar to the hilly tracts of peninsular India and Ceylon, while the small worm-like sub-terranean snake (*Typhlops*) is widely distributed all over the Indian Empire. Of the latter *Typhlops braminus* is the commonest. The best known Python or Rock-snake of India is *Python molurus*. The so-called Double-headed Snake kept by snake-charmers in this country is *Eryx jaculus* which lives in sandy tracts of Southern and N.W. India. *Cerberus rhynchops* lives in mud on the banks of large rivers and estuaries of the Indian region and feeds on fish. The Raj-samp or Banded Kraits (*Bungarus candidus*) of N. India are common all over the country and destructive to life. The King Cobra (*Naia hannah*) confined to parts of South and Eastern India and Burma, and to the Andamans is of fierce and aggressive habits and feeds on other snakes. *Echis carinata*, another fierce snake of the Viper class, may be met with in the desert or sandy tracts of India. The Pit-Vipers are represented in India by two species only, *e.g. Ancistrodon himalayanus* common in N.W. Himalayas and Assam and *A. hypnale* in Ceylon and the W. Ghats.

BATRACHIA.

Salamanders and Limbless Cæcilians.—The Frogs and Toads, the Newts and Salamanders, and the worm-like limbless Cæcilians which constitute this class have a peculiar distribution in India. The Indian Salamander is represented by a single species (*Tylototriton verrucosus*) which has hitherto been found only in the Eastern

Himalayas and the Shan plateau. The burrowing apodous Batrachians are represented by only five species belonging to 3 genera in the Indian fauna four of which are inhabitants of the Western Ghats of Malabar. The fifth species *Icthyophis glutinosus* occurs in the hills of Ceylon, Malabar, Eastern Himalayas, Assam and Burma in soft mud in damp places.

Frogs and Toads.—The Frogs and Toads are found everywhere in India in damp situations or in ponds, pools, and streams, and are aquatic, terrestrial, arboreal, or burrowing in habit. There are several genera of which *Rana* is the best known. All Indian species of this genus are probably aquatic during the breeding season, but their habits vary greatly. Over 40 species are known of which the most common are the truly aquatic *R. hexadactyla* of S. India and Ceylon, the large *R. tigrina* of all India and Ceylon, and *R. limnocharis* and *R. cyanophlyctis* of wide distribution in the Indian region. The last named live on trees or rocks or in very damp situations in the forests. Among the species of other genera may be mentioned *Micrixalus fuscus, Nannobatrachus beddomii* the smallest Batrachian known, *Rhacophorus maculatus* the 'Chunam Frog' of Madras, and *R. reticulatus* the female of which carries the ova in shallow pits in the skin of the ventral surface of the abdomen, and *Ixalus variabilis* of Ceylon, Malabar and the Nilgiris. Of the toothless Engystomatid Batrachians there are several small species represented in the Indian Empire of which the best known are *Microhyla rubra* of S. India and Ceylon, *M. ornata* of a much wider distribution; the burrowing form *Callula pulchra* with dilated digits, and the toad-like *Cacopus systoma* of peninsular India, Ceylon and Burma. Among the true Toads (Bufonidæ) the best known and the commonest species in the Indian Empire is *Bufo melanostictus*. There are two rare species belonging to families not common in the Indian region which deserve mention. One is *Caluella guttulata* of Burma (Family Dyscophidæ which is common in Madagascar) and the other is *Hyla annectens* (Family Hylidæ of Australia and America) known only from the hills of Assam and Upper Burma. The Burmese (*Leptobrachium carinense* of the rare family Pelobatidæ is known to attack with its strong jaws even small mammals.

Pisces.

The fish fauna of the Indian Empire is of considerable diversity owing to the great variety of habitats met with both in the sea and in the estuarine and freshwater areas. Fish are found everywhere along the coasts of India whether rocky, sandy or muddy, and amongst coral reefs, in deep sluggish rivers or in mountain torrents, in lakes, ponds and wells, in river estuaries, coastal lagoons and backwaters. The distribution of marine fishes is rather wide, and some genera are common to the Indo-Pacific and the Atlantic

regions. It was estimated by Alcock that 57 per cent. of the Indian marine genera were common to the Indian seas and to the Atlantic and Mediterranean. The freshwater fish fauna of the Indian sub-continent has elements in it which are common to the Indo-Malayan and Indo-Chinese regions. Barring the Chiclid *Etroplus* in S. India and Ceylon the African element is absent from most parts of peninsular India. The Lampreys and Hags (Marsipobranchii), the Chimæras or Elephant fishes (Chimæroidei), the Lung-fishes and Mud-sirens (Dipneusta), and the Sturgeons (Actinopteri) are totally absent in India.

Cartilaginous Fishes.—The Cartilaginous fishes such as Sharks, Rays and Skates are well-represented in the Indian seas and estuaries. The coastal waters and the seas in the neighbourhood of the Andaman and Nicobar islands abound in the much-feared large-sized Gray-sharks (*Scoliodon* and *Galeocerdo*), the Hammer-headed Sharks (*Zygæna*) and the Saw-fishes (*Pristis*), the Sting-rays (*Trygon*) with a spiny whip-like tail, the great Eagle-rays or Devil-fish (*Myliobatis*), and the Torpedos and Electric-rays (*Torpedo, Narcine*, *Bengalichthys*) some of which give a mild electric shock when handled. The dried fins of Sharks and Rays are exported to China, while some classes of people on the Indian coasts fancy the flesh of these fish. Some of the Sharks and Rays (*Scoliodon* and *Trygon*) ascend the large tidal rivers such as the Ganges.

Bony Fishes.—The bony fishes are, however, the most predominant and best-known fishes of the Indian Region both in the seas and in the fresh- and brackish-water areas. Only a few of the better known families of bony fishes can be mentioned in this Outline. There are several Eels (Symbranchoid, Murænoid) in marine and freshwater areas. Those which inhabit the coral-reefs or rocky shores are brilliantly coloured with bands and spots. The best known genera are *Anguilla* and *Muræna*. The freshwater Spiny-eel (*Mastacembelus*) belongs to another family and is not a true Eel. The scale-less Cat-fishes (Siluroidea) with their well-developed feeler-like barbels are found mostly in muddy rivers and their estuaries and in hill-streams. Some of these (*Wallago attu, Bagarius yarellii*) grow to large sizes and are referred to as 'Fresh-water Sharks'. There are a few marine genera such as *Arius*. The Carps (Cyprinoidea) are exclusively freshwater in habitat and include important food fishes such as Rohu (*Labeo rohita*), Catla (*Catla catla*), and Mahseer (*Barbus tor*) common in N. India. The Snake-headed Fishes (Ophicephalidæ) and the so-called Climbing-perch (*Anabas testudineus*) are common throughout the Indian Empire in rivers, ponds and marshes and have the power of living out of water for long periods. They are enabled to do so with the help of accessory respiratory organs which develop in various parts of the body (in the head in *Ophicephalus*, in the branchial chamber in *Clarias*, etc.). There are no true Salmon and Trout in India except those that have been introduced in the streams of the hilly parts of

the country. The Indian Herrings (Clupeidæ) include the celebrated migratory 'Hilsa' (*Hilsa ilisha*) of Bengal and 'Pala' of Sind closely allied to the Alice Shad of Europe, the Oil-sardine (*Clupea longiceps*) of the Malabar coast, and the Anchovies (*Engraulis*) are common on the Indian coasts and estuaries. The 'Bombay Duck' (*Harpodon nehereus*), the Gar-pikes (*Belone*) and Half-beaks (*Hemirhamphus*) are also common on the coasts and estuaries. The Flying-fish (*Exocœtus*) is, however, an inhabitant of the open sea. The Indian Perches comprise within it a large number of marine genera and a few freshwater ones (like *Ambassis*, *Nandus*, *Badis*, etc.) many of which include edible forms. The best known of the coastal or estuarine edible fishes are the famous 'Bhekti' (*Lates calcarifer*), 'Topsi' or Mango-fish (*Polynemus paradiseus*), Horse-mackerels (Carangidæ), true Mackerels (*Scomber*), Pomfrets (*Stromateus*), Tunny or Bonito (*Thynnus*), and Grey Mullets (Mugilidæ). Living among the coral reefs and along the rocky coasts are several small Percoid forms of bright colours belonging to the families Plesiopidæ, Glyphidodontidæ, and Labridæ. These are more common in the coastal waters of the Mergui Archipelago and the Andaman and Nicobar groups of islands. The Cod and Haddock (Gadidæ) of Europe are not well-represented in Indian waters, while the Soles and Turbots are represented by several species of Flat-fishes (Heterosomata) which do not have the same reputation as edible fishes as in Europe. The Globe-fishes (Tetradontidæ), the Pipe-fishes (Syngnathidæ) and the Sea-horses (Hippocampidæ) are quite common along the coastal regions and in estuaries, but members of the first two families have been found in freshwater at considerable distances from the sea. The mud-flats and river estuaries and mangrove-swamps have a fish fauna peculiar to such regions. Eel-like Gobioid fishes such as *Tœnioides*, *Pseudapocryptes* and *Apocryptes* burrow in mud where they æstivate in unfavourable seasons. The mud-skippers of the genera *Periophthalmus* and *Boleophthalmus* hop about on land far from the sea and the estuaries. A fish of a similar habit is the Blenniid *Andamia* which lives on rocky shores much above the water-line and sticks to rocks by a special sucker-like mental flap of skin when the surf beats against them.

In structure as well as in distribution the hill-stream fishes are of considerable interest. Several genera are known of which *Pseudecheneis*, *Balitora*, *Psilorhynchus*, *Parasilurus* and others are confined to the Eastern Himalayan region and are not found west of the Teesta valley. In S. Indian hills, *Bhavania*, *Silurus*, and *Parapsilorhynchus* occur and are closely allied to some of the E. Himalayan forms. There are no large inland lakes in India, but those of N. Burma such as the Inlé Lake and the Indawgyi Lake have endemic genera of exceptional interest such as *Chaudhuria* and *Indostomus*. These lakes, and some parts of Assam and the Abor country which are far removed from the sea coast have a peculiar fish fauna including genera common in the seas and estuaries or

their close allies. These genera are *Indostomus, Dorichthys, Tetraodon, Rhynchobdella* and *Moringua.*

Animal Communities in various environments.

A consideration of the Invertebrate fauna on the same lines as those of the Vertebrate would occupy far more space than is available for this Outline. We shall therefore give a brief account of the various groups of animals which actually occur or may be expected to occur in some of the common types of environments known in the Indian Region.[1]

Cave Fauna.

Caves of any large size or great depth comparable to those of Europe and N. America are not known in the Indian region, but in the limestone districts of Assam and Burma there are a few (Hsing-Daung, Ngot and Moulmein in Burma, and Cherrapunji and Siju in Assam), of which by far the largest known in the Indian Empire is the Siju cave in the Garo Hills of Assam. It is perhaps a matter of common knowledge that most dark places in India abound in Bats. These are the most characteristic animals of caves in general, and provide the bat-guano of high manurial value. The results of a careful investigation of the fauna of the Siju cave revealed a surprisingly small degree of adaptation to cave-life in the hundred and odd species found there. The majority of the species were such as those known to occur in daylight in other situations. Amongst the animals found at distances exceeding 1,500 feet from the entrance of the cave were land animals such as Bats (*Hipposideros*), Rats (*Rattus*) and Wild Cats (pug-marks of *Felis*), Isopods (*Philoscia* and *Cubaris*), Arachnids (*Heteropoda, Sijucavernicus, Schizomus*), Millipedes and Centipedes (*Trachyiulus, Himantostoma*), Insects (Collembola, Orthoptera, Diptera, Lepidoptera and Coleoptera), Earthworms (*Drawida, Megascolides, Glyphidrilus*); and aquatic animals such as Fish (*Nemachilus, Barbus*), Insects (the Gerrid bug, *Metrocoris* and the Gyrinid beetle, *Orechtochilus*) and Decapod Crustacea (*Paratelphusa, Palæmon*). The only species amongst these which show definite adaptation to life in caves, such as reduction in the extent of retinal pigment present in the eye or in the size of the cornea, and change in the colour of the body pigment, are *Palæmon cavernicola, Philoscia dobakholi* and *Cubaris cavernosus.* The land snail *Opeas cavernicola*, though found not further inside the cave than 500 feet from the entrance, shows modification in the eye. Kemp and Chopra, who investigated the fauna of this cave, are of the opinion that, on account of its comparatively recent origin, the fauna is in an early stage of evolution to the

[1] The following account of the animal communities in various environments has been critically examined by the author's colleagues, Drs. S. L. Hora and B. Chopra, to whom his thanks are due.

highly specialized state so characteristic of the older caves of Europe and America.

Desert Fauna (Plate VI, upper figure).

The little that is known of this fauna indicates that the species constituting it are widely distributed in India and adjacent regions, and are capable of physiological adaptation to the varied conditions of life. Annandale (1906)[1] observed that in the barren coastal plains of a South Indian District (Ramanad) the great majority of species represented have not only a wide distribution but are able to adapt themselves to various environments. Cockroaches (*Blatta* and *Stylopyga*) of this region, for instance, are found elsewhere in very damp situations. Most of the Wasps and Ants have a wide distribution in the Oriental Region. So are all the Butterflies except one (*Catachrysops pandava*). Some of the Arachnids (*Palamnœus* and *Buthus*) have a limited range in S. India. While certain forms such as the Gryllid, *Cophogryllus arenicola*, seem to be adapted to life in barren sand, the great majority of the larger forms are more hardy than specialized so that they are able to endure changing conditions of the environment. The colour of the Arthropods found was generally dull as in most desert localities, but those that were conspicuous had red or black pigment in the integument. Amongst the small Mammals found were the Fox (*Vulpes*), the Hedge-hog (*Erinaceus*), the Squirrel (*Funambulus*), Rats and Mice (*Tatera*, *Rattus*, *Leggada* and *Nesokia*), the Wild-cat (*Felis viverrina* ?) and the Hare (*Lepus nigricollis*). In the Salt Range of the Punjab (Hora 1923,[2] Pruthi, 1933[3]) the general conditions of life are not very favourable for terrestrial and aquatic life. The extremely hot and dry climate which prevails for the greater part of the year, and the high salinity of water in the streams and ponds as a result of the impregnation of the soil with mineral salts are inimical to a rich and abundant animal life. Even so the number of species of animals, terrestrial and aquatic (Reptiles, Batrachians, Fish, Worms, Molluscs, Crustaceans and Insects) which have made this region their home is well over a hundred, the most numerous of these being Insects such as aquatic and terrestrial Beetles, Dipterous Flies, May-flies, Dragon-flies, Caddis-flies, aquatic Bugs, and caterpillars of the aquatic Lepidopteran, *Aulacodes*. A large number of these is widely distributed in N. India or in the Oriental Region as a whole. A few, particularly the Reptiles and Molluscs, belong to the Afghan-Baluch-Persian desert region, and still fewer (Reptiles, Fish and Molluscs) are endemic. The only Palæarctic element in the fauna is a Toad (*Bufo viridis*) which is found outside the Salt Range in

[1] *Mem. As. Soc. Bengal*, I, pp. 183–202, pls. ix-x (1906).
[2] *Rec. Ind. Mus.*, XXV, pp. 369–76 (1923).
[3] *Rec. Ind. Mus.*, XXXV, pp. 87–119 (1933).

the Kashmir valley and in the districts north and west of the Punjab. The devastating invasions of Locusts (*Schistocerca gregaria*) of the years 1926–31 in N.W. India has focussed much attention on the distribution of this typically desert insect in Baluchistan, Sind and Rajputana where solitary forms of this Locust have been found over a wide area.

Hill-stream Fauna (Plate VI, lower figure).

The rapid or torrential streams of the hill-tracts or mountainous regions of India, Burma and Ceylon are inhabited by certain specialized types of animals of groups or families, representatives of which are found commonly in other types of environment such as large rivers, lakes, tanks and estuaries. The inhabitants of the torrential streams are generally members of the groups—Batrachia, Pisces, Mollusca, and Insects, but Leeches, Polyzoa and Turbellarians are also known to live in such environments (Hora, 1927). The environmental conditions in the hill-streams are by no means uniform (Hora, 1930). The slippery moss-grown edge of a boulder or rock over which the stream falls, the spray-covered bare rocks in the vicinity of the falls, the under-surface of submerged rocks and pebbles, the deeper rock-pools in the course of the stream, the marginal area of the stream which may have submerged or overhanging vegetation, all constitute types of environment commonly met with in hill-streams. Where rocks, pebbles, or coarse sand are present one may chance upon Batrachian larvæ (*Hylorana*, *Helophryne*, and *Megophrys*), Fish, such as *Garra*, *Sicyopterus* (of oceanic islands), *Glyptothorax* and *Pseudecheneis* with special adhesive organs which enable them to hold on to rocks, and Loaches (*Nemachilus*) which hide themselves amongst pebbles. Amongst insects which live under stones and pebbles or are attached to rocks are the immature stages of May-flies (Heptageniid Ephemeroptera), Caddis-worms (Trichoptera), Dragon-flies (Gomphid Odonata), Stone-flies (Perlidæ), Coleoptera (*Psephenus* and other Dryopid Beetles) Hemiptera (Naucorid Bugs), the Lepidopteran (*Aulacodes*) with its web-like larval cases, and Diptera (Empidæ, Simulidæ, Blepharoceridæ, and Psychodidæ). The larvæ either cling to rocks by hooks on the limbs and body, or adhere to them by sucker-like devices developed on the ventral surface of the body. Molluscs of the genera, *Paludomus* (Melaniidæ), *Theodoxis* (Neritidæ), *Turbinicola* (Ampullaridæ), and *Ancylus* (Ancylidæ) may also be found sticking firmly to rock-surfaces by means of their broad and muscular foot. In the pools in the course of hill-streams where the flow of water is not very rapid large forms such as the Batrachians, *Rana alticola* and *R. malabarica*, and small Carps (*Danio*, *Rasbora*, etc.), the Notonectid Bug, *Enithares*, Mollusca (*Melanoides*, *Acrostoma*, *Corbicula*) and Crustacea (*Caridina*, *Palæmon* and *Potamon*) may be met with. Living among the

aquatic plants of hill-streams are usually Tadpoles (*Megophrys*), Amphipods (*Gammarus*), Insect-larvæ or nymphs (Tipulidæ, Bætidæ, Simuliidæ, Chironomidæ) and the limpet-like Mollusc, *Ancylus*. Powerful swimmers amongst fish, such as *Barbus* (of the Mahseer type), *Labeo*, *Oreinus*, and *Barilius*, which occur in hill-streams are independent of the conditions governing life under rocks or in still pools of streams. They are of migratory habits and are often seen swimming against the current.

River Fauna.

The river-systems of the Indian Empire are not all of a uniform type, and the fauna of no one of them is completely known. The only river of which the upper reaches have been investigated is the Narbada where the faunistic elements are clearly those of the ordinary hill-stream type. Comparatively little is known of the middle reaches of rivers, but in the Ganges a distinct relict fauna has been observed. Among those included in this fauna are the Cetacean (*Platanista gangetica*), the Amphipod Crustacean (*Ampelisca pusilla*), the Bivalve Molluscs (*Scaphula deltæ* and *S. celox* and *Novaculina gangetica*) which have abandoned their ancient home in the sea and settled down to the conditions of life in the middle reaches of the Ganges. The Vertebrate elements of the rivers of India have already been dealt with in their appropriate places at the beginning of this Outline. It only remains to mention that certain Insects and Potamonid Crabs have a habitat closely associated with the banks and beds of rivers. The Gryllid *Tridactylus* is often found in great abundance in burrows in damp soil along large rivers and *Gryllotalpa africana* in moist sand of river-banks. In shallow rivers, particularly where there is a sandy bottom, Dragon-flies (*Ischnura*, *Agriocnemis* and *Onychogomphus*) are common, so are May-flies (*Anagenesia robusta*, *Polymitarcis indicus*) Caddis-flies (*Parasetodes bakeri*), and Water-beetles (the Dytiscid, *Laxophilus solutus*, the Gyrinid, *Orechtochilus gangeticus*, and the Hydrophilid, *Berosus fallax*).[1]

Estuarine Fauna (Plate VII).

The study of the estuarine fauna of rivers (such as that of the Ganges) has been of the highest scientific value from the point of view of the evolution of freshwater forms from marine ancestors. The comparatively low salinity of the waters of the Bay of Bengal which is constantly being diluted by the great freshwater effluents such as the Salween, the Irrawady, the Ganges, the Brahmaputra, the Mahanadi, the Godavari, the Kistna, and

[1] For these and other notes on the Insect fauna of various habitats the author is indebted to Mr. S. Rebiero, Entomological Assistant, Zoological Survey of India.

the Cauvery, and the gradual changes from the markedly less saline waters of the Bay of Bengal to the freshwaters of the rivers beyond tidal limits facilitate along these highways the immigration of marine forms into freshwaters by gradual adaptation to the *transitional conditions of existence in the estuaries.* The few observations that have been made in the river estuaries such as those of the Mahanadi, Indus, and Irrawady show that the character of the estuarine fauna in these rivers is essentially similar to that of the Ganges. In the muddy creeks and estuaries of the Gangetic delta a large variety of animal forms belonging to nearly all the more important groups of the animal kingdom except Echinodermata has been found. Many of the genera represented are either marine or brackishwater in origin, specialized or adapted to life in such situations as the mud-laden turbid waters, or the soft ooze-like bottom, or the tidal mud-flats (open or covered with mangrove) which are characteristic of the Gangetic delta. In these environments are found Sponges (Clionidæ and Suberitidæ) of distinctly marine origin, Hydrozoans (*Dicyclocoryne*, *Annulella*), Scyphomedusan jelly-fishes (*Netrostoma*, *Acromitus*), Actiniarian sea-anemones (*Edwardsia*, *Halianthus*, *Pelocœtes* and other Halcampactiids), Polychætes and Echiuroids (Nereidæ, Spionidæ, Capitellidæ and other families, and *Thalassema*), the pelagic *Sagitta*, Mollusca (Neritidæ, Littorinidæ, Assimineidæ, Auriculidæ, Rissoidæ, Nassidæ, Cerithidæ, Onchidiidæ, Cyrenidæ, and Mytilidæ) of brackishwater or marine origin, Polyzoa (*Barentsia*, *Loxosomatoides*, *Victorella*, *Bowerbankia*, and *Membranipora*) of brackish water origin, Crustacea (Entomostraca, Amphipods of the genera *Quadrivisio*, *Grandidierella*, Mysids such as *Potamomysis* and *Macropsis*, Penæid and Palæmonid prawns, Hymenosomatid, Portunid, Grapsid, and Ocypodid crabs), the King-crab (*Carcinoscorpius*), anadromous fish like the Indian herring, *Hilsa ilisha*, estuarine fish of the Siluroid group (Pangasiidæ, Ariidæ, Plotosidæ), the Herring and Gobies (Clupeidæ and Gobiidæ), and the Sting-rays (*Trygon*) of marine or brackishwater origin. Some of the forms enumerated above live in the ooze-like bottom mud, some live in burrows in thick mud between tide-marks or crawl on the surface, while others are active swimmers in muddy water. Certain adaptations to life in muddy waters, such as degenerate eyes, highly developed tactile organs, absence of bright colours except those of pink or red, the occurrence of resting buds and highly resistant non-sexual reproductive bodies are among those observed in certain groups of animals living in the Gangetic delta. The remarkable superficial resemblance of some of these specially adapted forms [Fish and Crustacea, which Kemp (1917) observed] to the deep-sea inhabitants of the same groups is a typical case of similar physical conditions (soft muddy bottom and low visibility) in different environments producing the same type of adaptation. Recent researches in estuarine waters have shown that the salinity of

bottom water in river estuaries is nearly the same as that of the sea and facilitates the penetration of bottom-living marine forms into the estuaries.

Backwater Fauna

The constituents of this fauna are as varied as those of the estuaries. There are several backwaters, lagoons and salty marshes on both the coasts of Peninsular India. The Salt Lakes of Calcutta (which are now almost fresh), the Chilka Lake on the Orissa Coast, the Vizagapatam backwater (now converted into a harbour), the backwaters of Pulicat, Ennur, and Adyar on the Madras coast, the extensive backwaters of Travancore, Cochin and Malabar on the west coast of India, and the broad barren sandy depression of land and water, the Rann of Cutch constitute the more important and well-known backwaters of India. They are more or less connected with the sea either temporarily or permanently by means of short channels or tidal creeks, and during the rainy season floodwaters enter them in such large quantities as to convert them into freshwater lakes. The fauna of these backwaters, as in the case of the Chilka Lake, is mainly of marine origin although there is a strong estuarine element as in the Gangetic delta. Apart from occasional immigrants into the Chilka lake from the sea and the adjacent freshwater areas the permanent inhabitants of the lake though not rich in species are found in large numbers and are capable of adapting themselves to the physical changes in their environment. With the exception of Echinoderms and Cephalopods, Pteropods, Cubomedusæ, and stony corals all other groups of the animal kingdom are well-represented in the various types of environment of the lake, such as the bottom of sand or mud or of both, the rocks, amongst weeds, and the mid- and surface-waters. The Salt Lakes of Calcutta although gradually becoming more and more fresh have a fauna which is distinctly estuarine in origin. Only a few species have established themselves in these lakes but the number of individuals of each species is very large. Among the commonest species found between 1926 and 1933 were Molluscs (*Melanoides lineata, Stenothyra deltœ, Modiola striatula, Cuspidaria annandalei*), Crustacea (*Varuna litterata, Palœmon lamarrei, Caridina nilotica, Mesopodopsis orientalis* and various Calanoid and Cyclopoid Copepods), and Coelenterates (*Phytocoetes gangetica* and *Campanulina ceylonensis*). The Pulicat Lake on the Madras coast was once an open bay but is now land-locked, and the occurrence of such genera as *Ostrea, Mactra, Arca, Murex* and *Calyptrea*, and *Balanus*, among Molluscs and Crustacea, *Polydora*, among Polychætes, and *Sycon* among Sponges shows that the fauna is entirely of marine origin. The Ennur and Adyar back-waters and those on the west coast have more or less similar features and are inhabited by a large number of marine and brackishwater forms. Amongst the latter are several interesting and perhaps

endemic species belonging to the groups Actiniaria, Annelida, Polychæta, and Mollusca.

Pond Fauna

The constituents of this fauna belong generally to certain widely distributed families and genera in the Indian Empire, and the genera and species which occur in a pond vary only slightly in different parts of the Indian Region. Amongst the small animals which occur in a pond with a muddy bottom and aquatic vegetation may be included snake-headed fish (*Ophicephalus*), Cat-fishes, Carp-minnows (*Puntius*), Top-minnows (*Panchax*) and other Cyprinodontid fishes, Perches, Ditch-eels (*Mastacembelus*), Turtles (*Trionyx*), and Frogs (*Rana*); Insects such as the Libellulid and Aeschnid dragon-flies, the Neuropterous *Sisyra indica* the larvæ of which commonly live in the canals of Sponges, May-flies (*Cœnis perpusilla*), Water-beetles, *Hydaticus vittatus* and *Cybister confusus*, the Gyrinid, *Dineutes indicus*, and the Hydrophilid, *Hydrophilus olivaceous*, aquatic Bugs and Water-scorpions (*Corixa*, *Nepa*), Caddis-worms (Trichoptera), Blood-worms (Chironomidæ), Mosquito-larvæ (Culicidæ); Water-mites (Acari); various Mollusca (*Lymnœa*, *Indoplanorbis*, *Gyraulus*, *Melanoides*, *Viviparus*, *Bithynia*, *Corbicula*, *Sphœrium*, *Potomida*, *Indonaia*, and *Lamellidens*); Polyzoa (*Hislopia*, *Lophopodella* and *Plumatella*); Leeches and Oligochæte worms; Crustacea (Potamonid crabs, Palæmonid prawns, Ostracods, *Cyclops* and *Daphnia* among Copepoda and Phyllopoda); various species of Wheel-animalcules (Rotifera); Sponges (*Spongilla*); *Hydra vulgaris*, and various Protozoa (chiefly *Amoeba*, *Vorticella* and other Ciliates, and a few Flagellates).

Lake Fauna

There are a few lakes, both in the plains and on the hills of the Indian Empire, of which the fauna has been investigated. The Manchar Lake of Sind in N.W. India, the Loktak Lake of Manipur in Assam, the Inlé and the Indawgyi Lakes of Burma are the only freshwater lakes of any large size. The animals found in these do not constitute a true lacustrine fauna, because of the admixture of a large paludine element in it. The lakes of India proper, namely the Manchar and the Loktak, have generally a poor fauna the members of which are not specialized, but the most abundant species are those of Fish and Molluscs. In the Burmese Lakes on the other hand the fauna is remarkably rich, more particularly in regard to Fish and Molluscs, both of which include peculiar and apparently endemic forms. In the Inlé Lake (Annandale, 1918)[1] representatives of nearly all the freshwater groups of the animal kingdom are present. Amongst the forms peculiar to the Lake may be mentioned the Turbellarian (*Planaria burmœnsis*), the Temnocephaloid (*Caridinicola*), the Crabs and Prawns (*Potamon curtobates*, *Palœmon naso*), several

[1] *Rec. Ind. Mus.*, XIV (1918).

aquatic Rhynchota (Notonectidæ, Corixidæ and Hydrometridæ), the Molluscs (*Lymnæa shanensis*, *Hydrobioides* and the Viviparid *Taia*), the Fish (*Barbus schanicus*, *Sawbwa resplendens*, *Microrasbora erythromicron*, *Mastacembelus oatesii* and *M. ocellatus*). In the Indawgyi Lake (Prashad and Mukerji, and Rao, 1929) on the other hand the fish fauna is fairly rich and the Mollusca are poorly represented. Amongst the fish, the Silurid, *Olyra horai*, the Cyprinid *Barbus sewelli* and *B. myitkyinæ*, and the curious pipe-fish like *Indostomus paradoxus*, and amongst the Molluscs, *Viviparus indawgyensis* and *Lymnæa decussatula* are the only endemic species present. One chief characteristic of the true lacustrine fauna of the Burmese Lakes is the occurrence of a large number of individuals of the endemic species.

Littoral and Beach Fauna.

It is somewhat difficult to give a generalized account of the fauna of the sea-coasts owing to the great variety of habitats. There may be long stretches of sand, or of sand and mud, broken up by creeks or swamps as on the east coast ; or the coast line may be rugged and rocky as on the Bombay coast. Fringing reefs in shallow water occur along the Gulf of Manaar, the Mergui Archipelago and the islands of the Andaman and Nicobar groups. In some places, as along the west coast of the Andamans, the reefs may have a formation not unlike that of a Barrier Reef. Atolls are characteristic of the Laccadive and Maldive groups of islands. The fauna of the sand and mud along the coasts consists of animals which burrow or live in burrows, and those that run or skip—Actinians (*Phytocœtes*, *Cerianthus*), Alcyonarians (*Virgularia*), Echiuroid worms (*Thalassema*), Sipunculoid worms (*Sipunculus*), Polychæte worms (Capitellidæ, Spionidæ and Ariciidæ), various Crabs (the Mole-crab *Hippa asiatica*, the Calling-crab *Uca annulipes*, and other species of *Scopimera*, *Dotilla*, *Macrophthalmus*, *Ocypoda*); Molluscs (*Harpa*, *Solen*, *Potamides*, *Pyrazus*), the Lancelets (*Dolichorhynchus*, *Branchiostoma*), and the Gobies—*Periophthalmus* and *Boleophthalmus*. A few insects (biting sand-flies, the carrion-eating Dipterous *Sarcophila cinerea*, the beetle *Cicindela biramosa*), the Hermit-crabs, *Coenobita*, *Birgus latro* (on the Sentinel Islands only), and the land-crabs, *Cardiosoma*, *Pelocarcinus*, *Geograpsus*, etc., usually haunt the sea-coast in search of food. The fauna of the coral reefs up to a depth of 1 fathom is perhaps the most varied and interesting from the point of view of the Invertebrate fauna and includes representatives of nearly all the groups of marine animals. Here one may find various forms of corals (Astræidæ, Madreporidæ and Poritidæ), encrusting Tetraxonid and other Sponges, Alcyonarians (*Alcyonium*, *Telesto*), Actinians (Phelliidæ and Sagartiidæ), various Echinoderms (*Holothuria*, *Synapta*, *Astropecten*, *Pentaceros*, *Ophiothrix*, *Temnopleurus*, *Echinometra*, etc.), tube-forming and free-living Polychætes, encrusting Polyzoa,

boring Sipunculoid worms (*Physcosoma, Aspidosiphon*), Turbellarians, various Mollusca (Chitons, Limpets, Trochidæ, Neritidæ, Littorinidæ, Cerithidæ, Cypræidæ, Nudibranchs), Crustacea (various Decapod crabs and prawns, lobsters, Alphæids, locust-shrimps, etc.) the Spider (*Desis inermis*), and the composite Tunicates (*Botryllus*, etc.). On rocks between tide-marks or at greater depths the fauna consists of various Hydroids, Actinians (Actiniidæ, Discosomidæ, Coralliomorphidæ, etc.), encrusting arborescent (*Dendrophyllia*) and solitary corals (*Heterocyathus*), Alcyonaria (*Spongodes, Pteroides*), Echinoderms (*Salmacis, Actinometra, Ophiocoma, Palmipes*), tube-forming Annelids (Serpulidæ), sedentary and boring Molluscs (Vermetidæ, *Lithodomus*), Crabs (Grapsidæ, Xanthidæ, etc.) and the Blenniid fish *Andamia*. The sea-weed fauna is almost as varied as that of the reef or rock fauna and includes Hydroids, small Actinians and Sponges, encrusting Polyzoa, small Nudibranchs, Amphipods, Oxyrhynch and Dromiid Crabs, and Pycnogonids. In rock pools one may find the corals *Porites* and *Meandrina*, the brittle star *Ophiothrix*, various Crustacea such as *Grapsus, Cryptodromia, Thalamita, Alphæus*, etc. and amongst fish the perches (*Pristipoma, Therapon*), grey mullets and eels.

Animals with a restricted or local distribution.

Before closing this Outline reference must be made to certain rare and interesting elements of the Indian fauna which have a more or less restricted area of distribution. Among these may be mentioned the Onychophoran, *Typhloperipatus williamsoni* (Kemp, 1914) found in chinks and crannies under large stones in scrub jungle at the foot of the Eastern Himalayas in the Abor country, the freshwater Littorinid *Cremnoconchus syhadrensis* which occurs at the edge of water falls at Khandalla in the Bombay Western Ghats (Hora, 1926), the Succineid *Lithotis rupicola* living in a similar habitat at Khandalla, the Aetheriid Bivalve *Mulleria dalyi* found hitherto only in the Kadur Dt. of Mysore State, the freshwater Medusa, *Limnocnida indica* (Rao, 1932) found in the smaller streams of the Upper Kistna river system on the eastern slopes of the Western Ghats, and the limbless Cæcilian, *Herpele fulleri* (Alcock, 1904) found only in the Cachar Dt. of Assam. Of these, the Molluscs are found nowhere else, and the occurrence of a Littorinid on the wet spray-covered cliffs of Khandalla far from the sea with a gill and a branchial chamber, and breathing unlike any known Pulmonate or Prosobranchiate Mollusca is indeed a remarkable fact of distribution. The Medusa has its closest relations in the freshwater lakes and rivers of Africa and China, while the only Indian representative of Onychophora from the E. Himalayas has close affinities with the Malayan species on the one hand and the Neotropical species on the other. The other species of the Cæcilian genus *Herpele* have been found only in W. Africa and the Panama region of America.

EXPLANATION OF PLATE V.

Sparse jungle in Burma with a herd of Bison (*Bibos gaurus*).

(See pp. 94–101 of the text for details of the fauna characteristic of sparse jungles in the Indian Region.)

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RAO: *The Fauna of India.*

PLATE V.

EXPLANATION OF PLATE VI.

FIG. 1.—Desert tract of Sind.

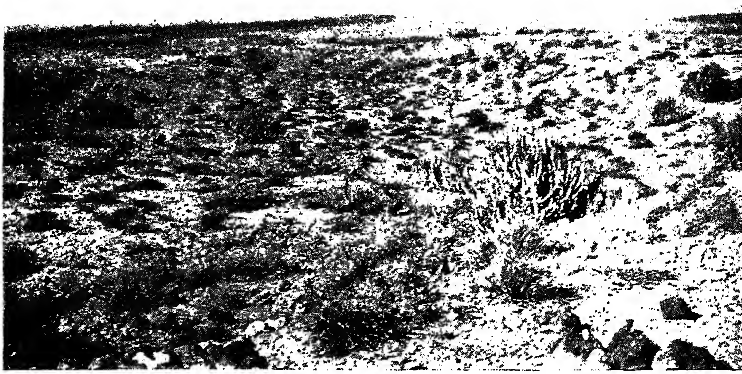
(See p. 117 of the text for the fauna characteristic of desert tracts.)

FIG. 2.—Water-fall and hill-stream, Khasi Hills, Assam.

(See p. 118 of the text for details of the hill-stream fauna.)

Both illustrations reproduced by courtesy of Bombay Natural History Society.

RAO : *The Fauna of India.* PLATE VI.



1.

2.

EXPLANATION OF PLATE VII.

FIG. 1.—Palm-fringed brackish water mud-flat, Sundarban.

FIG. 2.—Sundarban estuary of Malancha River, Bengal, at high tide.

(See pp. 119–121 for details of the fauna characteristic of estuaries.)

Both illustrations reproduced by courtesy of Bombay Natural History Society.

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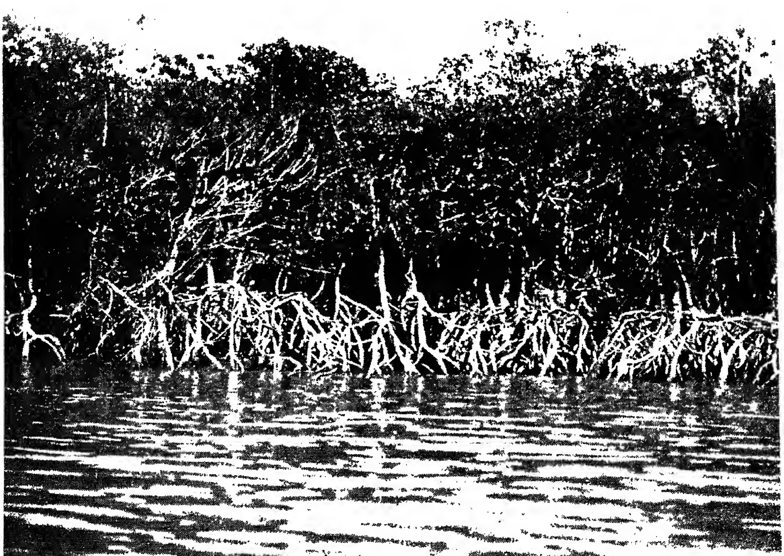

2.

AN OUTLINE OF THE RACIAL ETHNOLOGY OF INDIA.

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Contents.

Introduction : Pre- and Early-Historic Cultures and Races.

The ethnic composition of the people of India, consists, as elsewhere, of several racial strains, which came independently at different periods—from the Palæolithic to the Recent Historical times. Of the movements of Early Man we possess no direct evidence as to the regions from which he came, but in the control exercised by India's topographical conditions in directing racial movements into the country, we have some unmistakable pointers regarding the sources of these drifts. No racial invasion could have taken place from across the seas before the art of navigation was acquired by Man, and the mountain barriers on the North were likewise impassable. Man therefore could only have reached this country through the gaps in the mountain chains on her western frontiers. On the eastern side, the dense forests and the difficult mountain passes make it less probable for Early Man to have used these routes in any considerable extent. Very few artifacts as relics of Early Man's handiwork, have so far been recorded from these parts, but in the heart of the country itself, specially in

Central and Southern India, along riverbeds and hill terraces, crude and polished stone implements have been found in great abundance. But until recently we had no stratigraphic evidence of the age and culture-sequences of the Stone-Age Man in India. The Yale-Cambridge-India Expedition, which recently surveyed the Pleistocene in Kashmir and North-Western India, has not only found ample evidence of human occupations from the Early Palæolithic to the Late Neolithic times, but has also been able to at least tentatively fix their chronology by correlating them with the glacial cycle in the Kashmir regions. It appears that there were four major glaciations in the Himalayan regions with three interglacial periods. The earliest relics of human occupation such as 'rolled flakes and well-worked hand axes' closely resembling those belonging to the Acheulean Culture of Europe were found in the 'boulder conglomerate stage', about the end of the Second Ice advance. This hand-axe culture was replaced by another which appeared after a long erosion interval and lasted from the Second Interglacial to the Fourth Glacial Periods, and very appropriately named the 'Soan Culture' by de Terra from the presence of a large number of sites in the Soan Valley. This is essentially a flake culture and is typographically allied to the Moustierian flake industry of Western Europe. Over the remains of the Soan Culture abundant evidence was discovered of Microlithic, Proto-Neolithic and early Neolithic industries akin to that of North Europe and having also some resemblance to the Upper Palæolithic Cultures of North Africa. De Terra's Survey was fruitful in another direction also. In the excavation of the Megalithic site at Burzahom, near Srinagar in Kashmir, he discovered in the lower strata (Late Neolithic), a black varnished ceramic ware identical with those found in Mohenjo-daro. His investigations, therefore, not only carried the prehistory of Man in the Indus Valley to the beginning of lithic industries, but has provided, what may prove to be the link connecting the Neolithic and Chalcolithic Civilizations of India. De Terra's and Teilhard's Survey of the Narbadda Valley and the Palæolithic site of Khandivli, about 20 miles from Bombay, showed further the extension of the Lower Pleistocene and the Soan Cultures of the Indus Valley to these regions, proving if proof was needed, that the Palæolithic man must have entered India through the North-West, and spread gradually throughout Central and Western India. It is also probable that the Stone Age cultures of Southern India were only extensions of those of the Narbadda Valley.

Unfortunately however, no trace of the skeletal remains of Early Man associated with these finds, has so far been discovered in any part of India enabling us to judge his physical type and of his possible affinities with the Stone Age races of Europe and other parts of Asia. Indeed with the exception of the fossil skull found at Bayana, but which is of uncertain antiquity, the skeletal remains

that may definitely be considered as providing landmarks in the racial history of India, are those belonging to the Indus Civilization between the third and the second millenia B.C., and the remains of the monks etc. at the Dharmarajika Monastery at Taxilla which was sacked by the White Huns in the Fifth Century A.D. The innumerable ruins of a Megalithic character, which are strewn all over Western, Central and Southern India, undoubtedly treasure a wealth of skeletal materials but with the exception of a small number—and these mostly by European Explorers—very few of these ruins have so far been excavated.

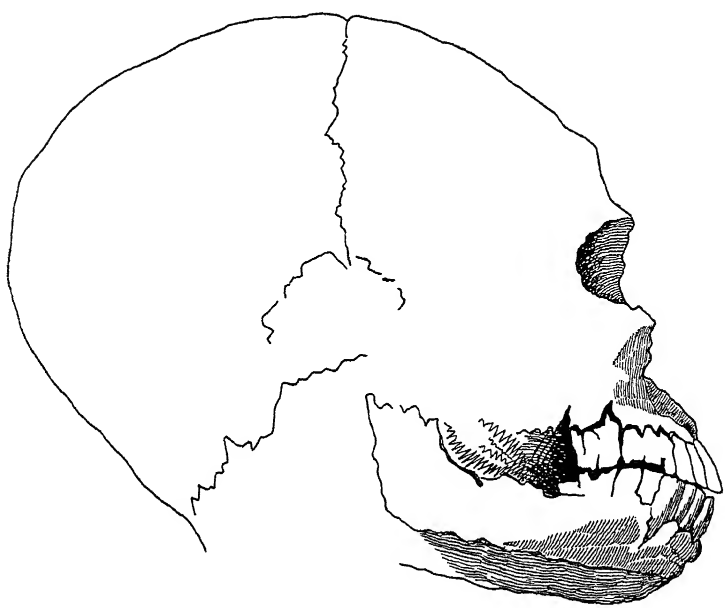
If we consider the skeletal remains during the Chalcolithic times, the population of the Indus Valley consisted in the main of moderate statured people with long head, narrow prominent nose and long face, but not physically very powerful. There was also present another long-headed type, very powerfully built and possessing a tall stature. They had stout eyebrow regions and were very large-brained—the average cranial capacity being higher than that of the modern European. A characteristic feature of this race was the enormous growth of the post-auricular parts of the skull, forming in some cases more than half of the total cranium. In addition to these two long-headed strains, there was a distinctly broad-headed element with high cranial vault and prominent nose. The back of the skull among this type varied from a round to a vertical flat shape of the Armenoid Race. All these three groups also occurred in ancient Al-Ubaid and Kish, showing that the racial strains of pre-Sargonic Mesopotamia and the Indus Valley during the Chalcolithic times, were closely allied.

The prehistoric sites so far excavated in Central and South India, are all associated with Iron, and are probably of a much later date. From one of these sites only, namely that of Aditanallur in the Tinnevelly district of the Madras Presidency, several human skeletons have been recovered. In the rest, the evidence available is very scanty, either because the excavators were not acquainted with the scientific technique employed in the preservation of bones or that they did not consider them to be of sufficient importance to preserve !

The majority of the skulls from Aditanallur discloses a dolichocranial and mesorrhine type not unlike the one which underlies, in a large measure, the present Indian population. The late Prof. Elliot Smith, who examined some of the better preserved specimens from the Madras Museum, noticed a definitely Australoid and an Armenoid strain among them. Lastly Meadows Taylor, who was one of the earliest investigators of the Megalithic monuments of South India, has published the drawing of a skull from the famous ruins of Jewurgi showing pronounced negroid characteristics.

Of the early historical period our materials are mainly confined to the human remains discovered at the Dharmarajika Monastery

at Taxilla which was sacked by the White Huns about the end of the 5th Century A.D. The racial type disclosed here is also long-headed but possessing a lower cranial vault and a larger head breadth. The posterior parts of the skull are not markedly developed. The face is very long and the nose fine and highly pitched. All these traits clearly distinguish these remains from those of the Indus Valley during the Chalcolithic times, and suggest the possibility of a later racial drift.



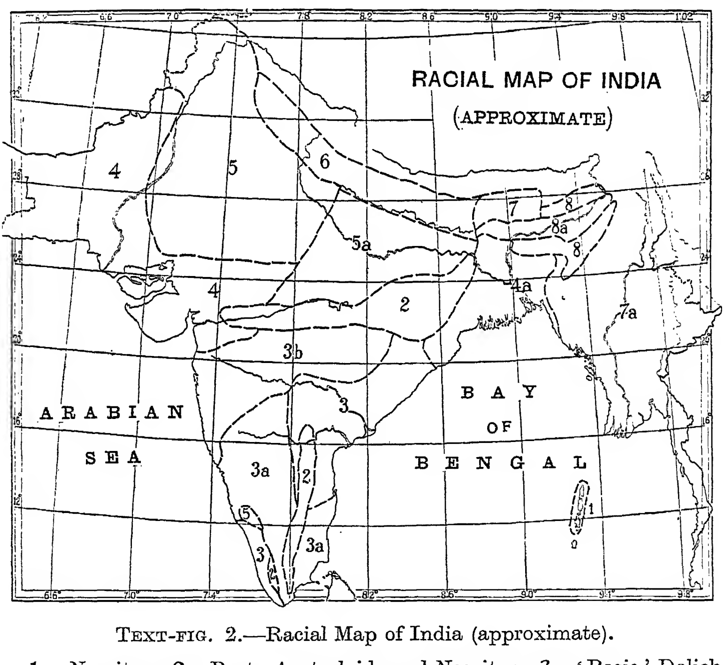
TEXT-FIG. 1.—Outline drawing of the skull from Jewurgi. Reproduced from Meadows Taylor.

These are about all the evidences we have on the racial types of Man during pre- and early-historic times in India. They are unquestionably very meagre and defective, and deal only with a small section of India's racial history. Of the rest of the early racial movements we have no information either as to the time of their advents or the precise nature of their ethnic compositions. However, such as the materials are, they nevertheless enable us to trace, at least some of the major strains in the modern Indian population, to prehistoric times.

ETHNIC COMPOSITION OF PRESENT-DAY INDIA.

The Negritos

We have no bony remains of a definitely Negrito race from any of the prehistoric burials so far excavated, but the drawing of the Jewurgi skull (text-fig. 1) from Cairn E, published by Meadows Taylor is undoubtedly Negroid. The presence of the Negrito race in the Andaman Islands and in the interior of the Malay Peninsula has been known for a long time, but in the mainland of India, its presence though suspected was hitherto not confirmed. Hutton, however, has recently shown that frizzly hair is not an infrequent occurrence among the Angami Nagas and I have drawn attention to the presence of spirally curved hair—as did also Lapique—among the Kadars and Pulayans of the Perambiculam and the adjoining Annaimalais Hills of Southern



TEXT-FIG. 2.—Racial Map of India (approximate).

1. Negritos; **2.** Proto-Australoids and Negritos; **3.** 'Basic' Dolichos and Proto-Australoids; **3a.** 'Basic' Dolichos Alpo-Dinarics and Proto-Australoids; **3b.** 'Basic' Dolichos, Alpo-Dinarics and Proto-Australoids with small elements of Orientals and Proto-Nordics; **4.** Alpo-Dinarics and Orientals with a sprinkling of Proto-Nordics; **4a.** Alpo-Dinarics and 'Basic' Dolichos with small proportion of Indus and Proto-Nordic types; **5.** Proto-Nordics and Indus with some amount of Orientals; **5a.** Indus and Proto-Nordics with 'Basic' Dolichos as a small element; **6.** Orientals and Brachy Mongoloids; **7.** Brachycephalic Mongoloids; **7a.** Short Brachy Mongoloids; **8.** Dolichocephalic Mongoloids; **8a.** Dolicho-Mongoloids with a small proportion of 'Basic' Dolichos and Alpo-Dinarics.

India. The Andamanese, as is well known, are a black pigmy race, living in the forests of the islands of the same name in the Bay of Bengal, which have sheltered them from an immemorial time, though in view of their rapid extermination, it is doubtful how long they will continue to do so. They have a dark chocolate brown skin colour approaching black, with wooly hair, often having vacant intervening spaces between little knots of hair. Their head is broad, the face round and the nose flat and broad. Steotopygia is present among women and also to some extent among men. Among the Kadars, the mean stature is slightly higher, being 1556 mm. against 1486 mm. for Andamanese males. The average skin colour is also dark chocolate brown, but not quite black. The hair is of the frizzly type, with long spirals resembling those of the Malenesians of New Guinea. Short spirals—but not of the pepper-corn type—though rare are not altogether absent. The face is short and often projects forwards with broad short noses and thick everted lips. What distinguishes the Kadars from the Andamanese however is the shape of the head. It is never truly brachycephalic as that of the Andamanese, but long, though among some of the frizzly haired men, the Cephalic index rises up to 79.29. In this respect the Kadars resemble more the Semangs of the Malay Peninsula, who are also mesocephalic, but closer still the Malenesians, who are predominantly dolichocephalic with long spirally curved hair (Plate VIII, figs. 1–3).

What exactly was the original type of the Indian Negritos is of course difficult to say. But judging from the recent discovery of Mr. Sarkar (*Nature*, CXXXVII, p. 1035, 1936) of a brachycephalic young man with clear wooly hair among the aborigines of the Rajmahal Hills of Bihar (Plate VIII, fig. 4) and the presence of mesocephals among the Kadars, it seems not improbable that the original type was not unlike that of the neighbouring Negrito tribes, specially the Semangs, who it is interesting to observe, possess a large number of designs in their combs identical with many of those used by the Kadars. It is true that at the present moment we have a few remnants only of this race in specially isolated tracts, but judging from its presence among the Angamis in the North East, Bagdis of the Rajmahal Hills of Bihar, and the Kadars of the extreme South West, it appears not unlikely that it had at one time a much wider distribution, though now submerged, excepting in these marginal areas where it has managed to survive as the last relics of an ancient race.

The Proto-Australoids

The Australoid type so conspicuous in the Tinnevelley sites in the prehistoric times and in other Megalithic remains of Peninsular India is one of the major elements in the aboriginal population of this country. A comparison of Aditanallur skulls with some of the authentic Munda crania in the collections of the Indian Museum, leaves no room for doubt that in the general shape of the cranium,

the development of the lower forehead, the depression of the nasal root, the breadth of the nasal bones and in the projection of the facial parts, the two are essentially alike.

Among the aboriginal Indian population, specially those of Central and Southern India, there are many who show a marked development of the supra-orbital ridges along with a sunken nasal root, but in the majority however, this trait is not pronounced, though in the shape of the head, the form of the nose, the projection of the face, skin colour and structure of hair no significant differences are observed.

If we compare these tribes with the Veddas of Ceylon, and the aborigines of Australia, we find that in the shape of the head and the face, the form of hair and, skin colour, the three are essentially alike, though the Australians are taller and show larger absolute dimensions of head than the other two. The Veddas are closer to the Australians, than to the Indian tribes, who are the smallest of the three. Among the Australians also the brow ridges are more marked and the body hair is more profuse. In all these characters there seems to be a regular gradation, the shortest and the smallest being the Indian tribes, then come the Veddas, and lastly the Australians. We may assume then that all the three belong essentially to the same stock, the Indian tribes retaining the more basic characters, and the two extra-Indian groups having developed some of the features in a more marked manner. The most appropriate term to apply to them therefore is *Proto-Australoid* which shows best the genetic relationships between the three (Plate VIII, figs. 5-6).

The whole of the Central and Southern Indian tribes belong essentially to this type, though pertaining to different linguistic families. The same can be said of the tribes of Western India and the partially reclaimed groups in the Gangetic Valleys who form the outer layer of the Hindu social system at the present times. The Bhils, Kols, Badagas, Korwa, Kharwar, Munda, Bhumij and Malpaharias living in the Central Indian highlands and the Chenchus, Kurumbas, Malayans and Yeruvas of South India may be regarded as some of the representatives of this race, though the amount of admixture with other types specially the Negritos, in each of these tribes is not uniform. It is certainly stronger among the tribes living in the marginal areas of S. India than among the Central Indian groups.

We have no definite evidence as to the times of the respective drifts of these races into India but judging from their distribution, the Proto-Australoids appear to be later, whose pressure it may be presumed, the more primitive Negritos were not able to withstand and were gradually driven off to less hospitable regions. In the process of this expansion, the Proto-Australoids unquestionably have absorbed a large amount of their blood in varying proportions, to which must be ascribed some of the differences

noticeable in these tribes—specially between those of the Central Indian highlands and the Southern Indian hills.

The Basic Dolichocephalic Type

One thing that comes out most clearly when the somatic characters of the people inhabiting the plains of India are compared, after the various aboriginal strains are eliminated, is the predominance of a type of medium statured, long headed people. It is characterized by high cranial vault, a narrow, vertical forehead often bulging, with the supra-orbital ridges but faintly marked. The face is short with prominent cheek bones and pointed weak chin. The nose is moderately prominent and long but the nostrils are spread out giving a low mesorrhine index. The lips are full and the mouth is large. The skin colour varies from a rich to a dark tawny brown and the eye is invariably black. The hair is straight but inclined to be wavy and is moderately present both on the face and the body (Plate VIII, figs. 9–12).

This is the type par excellence of Southern and a large component of the lower section of the population of Northern India, though among the upper classes even, it is not altogether unknown. It has been suggested that this race has evolved in the open grasslands of the Deccan out of the Proto-Australoid race mentioned before. I find this view difficult to accept for several reasons, one of which is, that it is universally acknowledged that the form of the nose has a great diagnostic value in the differentiation of races, but it has also been shown that warm and moist climate has a tendency to broaden the nostrils by 'snuffing up great quantities of warm and moist air through the nose', whereas, 'the cold air of northern climates needs to be warmed up by passing through a high narrow nose charged with blood'. If this be so, it is inconceivable how the flat broad nostrils seen among the aborigines of Central and Southern India, could become narrower and more pronounced after prolonged habitation in the hot and moist climate of the Indian plains.

A second and more weighty consideration in the close resemblance of this race with that described by Elliot Smith from the skeletons found in the Pre-Dynastic graves of Upper Egypt. Here also the type is long headed and the body long and slender. The forehead is similarly vertical and bulging with poorly developed eyebrow ridges and the nose small and likewise broad. We have no evidence as to when this race first came to India but among the crania found at Aditanallur and several of the Cairns of the Deccan, it occurs as the prevalent type. In Europe, the Megalithic monuments are assigned to the Late Neolithic times and the racial affinities of the people who introduced that culture are broadly classed as Cro-magnon. We have seen that Dr. de Terra has definitely established that in the N.-W. India, the Megalithic remains also belonged to the same times. In Central and Southern

India, on the other hand, the Megalithic Culture was associated with bronze and iron and must have been more recent. The high percentage of tin in the bronze objects of Aditanallur and the Cairns of the Deccan and Central India, shows the intimate connection between the cultures of these places, as against that of the Indus Valley where the percentage of tin is very low.

We have not found so far any remains of man in the Megalithic sites of North-Western India, but from the crania discovered at Aditanallur and the Deccan Cairns, it would seem that a race allied to the one which inhabited the Pre-Dynastic Egypt and appeared to have a wide distribution, from North Africa to the Indian frontiers in ancient times, brought this culture to India during the Neolithic times. The presence of bronze and iron objects in Central and Southern Indian sites, however indicates, that the use of these metals was learnt subsequently—probably in the Indus Valley, and with this knowledge they were able to work the easily procurable copper and iron ores, when pushed to the plateaus of Central India, and from where they gradually spread over the whole of the Deccan and Southern India, conquering and partially mixing with the older Proto-Australoid races, who in their turn had driven out and absorbed the more primitive Negrito tribes.

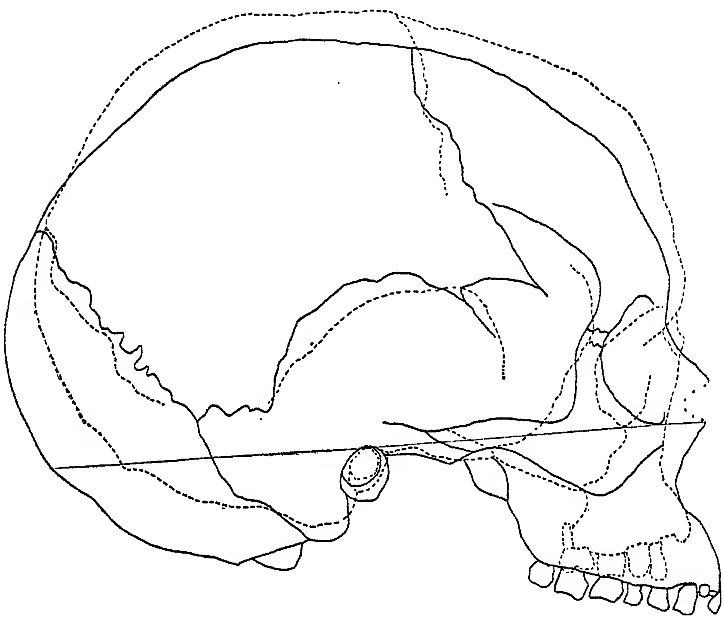
The Large-brained Chalcolithic Type

This older and more basic strain must be distinguished from the two dolichocephalic types found in the Indus Valley during the Chalcolithic times. The powerfully built large-brained race with well developed supra-orbital regions and enormous growth of the post-auricular parts of the skull, whose earliest relics are found at Mekran, the open burials of Harappa, and the lower strata of Mohenjo-daro, survives to this day in the population of N.-W. India as shown from Eickstedt's discovery of 'a coarse type with robust proportions, overhanging occiput and prominent superciliary ridges but with lighter complexion' among the Punjabi soldiers imprisoned by Germany during the War. The more delicately made smaller type with sharp well-cut features and fine narrow nose, whose remains were also found in abundance in all the sites from Nal to Mohenjo-daro, though resembling the Cairn builders of S. India in stature, slenderly built bodies and smooth eyebrow regions is nevertheless distinguished from it by more refined features, lower cranial vault, well arched forehead and narrow high pitched nose. Its affinities therefore are closer with the Mediterranean race of Europe as distinguished from the older Badarian strain with which the South Indian appears to have been intimately connected.

The Indus Type

In India this ancient 'Indus type'—to call it from the place of its earliest occurrence—seems to be later than the previous type, and as far as can be judged, responsible for the civilization

which developed on the banks of the Indus. Without doubt this early race has entered largely in the composition of the population of Northern India, specially the upper section, and provides one of the bases for that sharp distinction which marks the people of Northern from Southern India, though among the Brahmins there, and upper classes, its presence is unmistakable (Plate VIII, figs. 13–16).



TEXT-FIG. 3.—Composite profile drawings of Aditanallur 'Basic dolichocephalic' (..........) and Mohenjo-Daro 'Indus' (—————) skulls, superimposed. $\times \frac{1}{2}$.

The Alpo-Dinaric Type

On the racial framework thus built there has entered from the North-west (i) a Non-Mongoloid Brachycephalic race with round and broad face and long prominent nose. The earliest evidence of this race is found at Mohenjo-daro during the Indus period. In Harappa it occurs more frequently, specially at a somewhat later date, and it is here for the first time that the plano or flattened occiput so characteristic of the Armenoid race is met with. Elliot Smith reported the occurrence of a similar type at Aditanallur, and in some of the crania excavated from the Cairns of Hyderabad by Hunt, its presence was also noticed. At the present moment

the Brachycephalic Non-Mongoloid races are dominant in Guzrat, Kanara and Bengal, and mixed with the older basic long-headed type and the Proto-Australoid races, it occurs very largely in the Maharashtra and the Tamil country. There is a certain amount of local variation in this type, that of Guzrat for instance being shorter and lighter in skin colour than the rest—but in the fundamental traits there is an essential agreement, showing that the basic type was one or closely allied. In general terms this can be described as of short to medium stature, broad high head with somewhat receding forehead, and plano or flattened vertically inclined occiput. The face is short among the Guzratis but longer in Bengal, and the long nose is prominent and often arched and convex specially in the former. The skin colour varies from a pale olive among the Nagar Brahmins and Coorgis, and light brown among the Bengali Kayastha, to dark tawny brown among the Tamil Chettis. The eyes are round and horizontal and the hair is generally straight and profuse on the face and body. In general shape and features the affinities of this type are closer with the 'Dinaric' race of Eastern Europe rather than with those of the 'Armenoid' who possess some of the characteristics in a specially intensified form (Plate IX, figs. 5–12).

The recent discoveries of Bertram Thomas have definitely established the existence of brachycephalic types in South Arabia of which the 'Omani' appears to be Armenoid. We have no evidence of its occurrence in India before the Chalcolithic times, but from then onwards it certainly had drifted along the Western littoral into Kannada and Tamil lands, leaving Malabar and Andhra unaffected. An eastward movement seems to have penetrated early into the Gangetic delta leaving a distinct trail in Central India and Bihar. No adequate reasons exist for thinking, as some have done, that the brachycephaly in the Gangetic delta is continuous with that existing in the plains of Burma. Apart from fundamental differences in the physical types in these two places, the dense forests and the mountain barriers formed by the Patkoi, Naga-Lushai, and the Arakan-Yoma Hills extending up to Cape Negrais, are formidable obstacles against any migration coming from the Burma side. The origin of the brachycephalic strain in the Gangetic delta is the same as that of Western India and is probably the result of racial movements in South-west Siberia during prehistoric times which caused similar or closely allied types to appear also in Eastern Europe and Southern Arabia.

The Proto-Nordic Type

(ii) The racial invasion which has however caused the most profound change in shaping the culture and history of India is the one associated with the advent of the Vedic Aryans somewhere in the second millenium B.C. We have no skeletal remains from ancient India which can be definitely attributed to them, but in those recently discovered in the Dharmarajika monastery at

Taxilla, we probably get some idea of their racial type though of much later times. The monastery was sacked by the White Huns in the fifth century A.D. and with the exception of one, all the human skeletons were apparently those of the monks who occupied the monastery. The features that distinguish these skulls from the other long-headed types found so far in India, are their comparative broadness, lower vault of their cranium and a mean cubic capacity as high as 1552 c.c. The nose is very highly pitched and narrow and the face well built and long. The lower jaw is powerfully made and the whole cranium and face give the impression of great physical strength. At the present moment the type is found as the dominant element throughout the N.-W. Frontiers among the various Pathan tribes, mixed with what Eugen Fischer has called the 'Oriental' race. Among the tribes living in the valleys formed by the Upper Indus and its tributaries of the Swat, Panjkora, Kunar, and Chitral it is found in its purest forms, specially in the Kaffir tribes of the Hindukush mountains. In the Punjab and Rajputana and the higher classes of Upper India it is also marked but increasingly more mixed with the two older types of dolichocephaly already mentioned. There is also a sprinkling of it in the rest of Northern and Western India but nowhere dominant (Plate IX, figs. 13–16).

Among the Northern Mountain tribes 'the milk just tinged with coffee' skin colour of the North Indian upper classes, changes into the rosy white of North Europeans and there is a good percentage of grey and blue-grey eyes, sometimes accompanied by chestnut or red hair. Robertson wrote of the golden hair among the Red Kaffir women but I have found no instance of a truly golden or flaxen hair among any of these people, but of course Robertson had a much longer and wider acquaintance with them, while my knowledge was confined to the valleys of the Rambur and Bamboret and the adjoining hinterlands. Generally speaking however, the hair among these peoples varies from a brown to a light brown colour, but occasionally one notices a reddish tint. I doubt however, if this race in India can be strictly termed 'blond' in the same sense in which the people of Northern Europe are called. They can be more accurately described as partially blond or Proto-Nordics. Eugen Fischer has stated that the upper castes of Northern India retain the Nordic characters of stature, head and the nose without the fair tint of the skin. In the hot climate of the Indian plains, the blonds were no doubt eliminated by natural selection, but if the hair colour of the Kaffir and the allied tribes now living in the cold secluded regions of the Hindukush mountains, be of any indication, the original type among the Vedic Aryans could not have been completely blond—a trait which appeared to have developed subsequently in its present form among the people living around the Baltic. The presence of light eyes among the Chitpavan Brahmins of Bombay, and in a very small degree among those of the United Provinces, Bihar and Bengal, shows that the influence of

this type extended far beyond the North-Western parts, of which traces alone now remain in the outlying regions.

The Oriental Type

(iii) In addition to this lighter element, in the whole of the North-West there is another intruding element which Fischer has called the 'Oriental'. In this the skin colour is fair but the eyes and hair are black and the nose is markedly long and aquiline. Among the Badakhsis of Northern Afghanistan this is the dominant type, and throughout the Pathan country from Dir to the Khybar it forms a strong layer. The short longheaded type which extends from Chitral to Western Nepal, and is the characteristic type of the Himalaya Mountains, appears to be a variant of this type, and must have come very early into the Western Himalayas from where it had spread all along the sub-Himalayan regions (Plate IX, figs. 1–4).

In the plains of India the 'Oriental' strain, though present, is not however strongly felt except in the Punjab where it is conspicuous among certain sections. Among the higher classes of the Moslems of Upper India, the 'Oriental' type also survives as the relic probably of the Pathan invaders, who as judged by the Badakshis of North Afghanistan must have contained this element.

The Tibetan Type

The main movements of the Mongoloid races appear, to have passed by India without affecting its population to any considerable extent, except the sub-Himalayan region, Assam, and the lands adjoining the Eastern Frontiers and Burma. The true Mongol races, as seen among the Turki speaking peoples living in Chinese Turkistan, and in and around the Taklamakan Desert, such as the various Khirgiz, Kalmuck and the Uzbeg tribes, as yet remain outside the Frontiers of India excepting the plateaus south-east of the Karakoram Ranges adjoining Tibet, where the Chiangpa have made their home. They are an intruding race of pure Tibetan origins. The more north-westerly Ladakhi also show distinct mongoloid characters such as high cheek bones and oblique slit-eyes, but contains at basis the racial strain characteristic of their neighbours, the Purigi and Machnopa, etc. which appears, as has been already remarked, to be a variant of the 'Oriental' race which settled very early in the Western Himalayas. From the Chiangpa to the Bhutan Hills north of Assam, the Tibetan strain appears as the dominant element amongst the Lahoulis, the Limbu, the Lepcha and the Rongpa, who occupy the entire mountain valleys as far east as the Bhutan Hills. The chief characteristics of this strain is medium to tall stature, round broad head and face, with high cheek bones and long flat nose. There is very little hair on the face and the body, and the skin colour is light brown tinged with a reddish tint (Plate VIII, fig. 7). In Nepal proper, the people exhibit a gradual increase of mongoloid blood as one proceeds east and northwards; the basic type, however appearing

to be the same Non-Mongoloid strain as in the Western Himalayas. The Gurung, Murmi and the Gurkha tribes who represent the mongoloid element are darker and shorter than the Tibetan proper, with smaller broader nose and less flat face, and represents a distinct local group.

The Dolichocephalic Mongoloid Type

The tribes living in the hills on the Northern and Eastern Frontiers of Assam represent a separate type with a head shape either wholly or with a tendency to be dolichocephalic, the transverse diameter being narrower, and the occiput protruding somewhat. In the flatness of the nose, face, high cheek bones, oblique slit-eyes and absence of hair on the face and the body, they are however essentially mongoloid, and must be regarded as a different branch of that great race which entered from South-Western China, and whose main body moved away towards the Indonesian islands through Burma and the Malay Peninsula, leaving a side-stream in the Assam Hills, such as that represented by the Miri, Bodo and the Naga tribes, and underlies the population of the Assam Valley in general, whose upper stratum however, shows traces of the non-mongoloid longheaded and possibly brachycephalic strains which introduced Hindu Culture from Upper India (Plate VIII, fig. 8).

Brachycephalic short Mongoloid Type

In Burma, the racial type again is broad headed but short and rather dark, and seems to be more closely allied to the Malays rather than to the taller and longer headed Assamese tribes. The Chakmas of the Tipperah, and the Mog tribes of the Arakan-Yoma Hills, appear to be the north-westernmost extensions of this type; but excepting in the Chittagong districts and the strips adjoining the hills, neither of the two mongoloid strains appear to have affected the population of the Bengal plains, whose characteristic type is found in the central deltaic parts, rather than in the outlying districts.

The Oceanic Type

The above are the main strains in the racial composition of the people of Hindusthan. There were, however, some minor drifts also, one of which came from Oceania bringing the Outrigger Canoe and Cocoanut with it. Its influence appears however to have been confined chiefly to the southernmost strip of the Tamil Nad and Malabar, though it is possible that a wave of this movement reached as far north as Orissa. It is probable that this factor is responsible for the slight mongoloid strain seen among some of the peoples of these regions.

Concluding Remarks.

In the preceding pages an attempt has been made at indicating the main landmarks of the Racial History of India, and the

probable origin and distribution of the component strains which have gone to make up the Indian people. The exact contribution of each race, however, to the formation of the various types that we notice at present, is difficult to assess, as our knowledge of the factors that control the reshuffling of genes in a mixed population, to produce the various recombinations is still far from satisfactory. Similarly the distribution of the main types into separate ethnic zones is only true in a general sense, for there is a considerable overlapping of types and no rigid division is possible in many cases, though broadly speaking a zone of Proto-Nordics mixed with the Mediterranean and the Oriental in North-Western India, can be distinguished from a Peninsular Indian one containing an older and more primitive Dolichocephalic strain. On both sides of this is to be found the Plano-Occipital Brachycephalic race mixed with the types mentioned above. The Mongoloids occupy chiefly the submountain regions in the North and the East, while the dark aboriginal tribes are scattered all over the Peninsular highlands, and many parts of the Upper Indian plains.

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EXPLANATION OF PLATE VIII.

Negrito Type.

FIG. 1.—Andamanese woman.

FIGS. 2-3.—Kadars from Cochin hills.

FIG. 4.—Aborigine from Rajmahal hills of Santal Parganas, Bengal.

Proto-Australoid Type.

FIG. 5.—Chenchu from Hyderabad-Deccan.

FIG. 6.—Malayan woman from Cochin.

Mongoloid Type.

FIG. 7.—Mongol from N.-W. Tibet.

FIG. 8.—Sema Naga from the Naga hills, Assam.

Basic Dolichocephals.

FIGS. 9-10.—Tamil Brahmins of Madura.

FIG. 11.—Illuva lady from Cochin.

FIG. 12.—Telegu Brahmin of Vizagapatam.

Indus or Mediterranean Type.

FIG. 13.—Nambudiri Brahmin of Cochin.

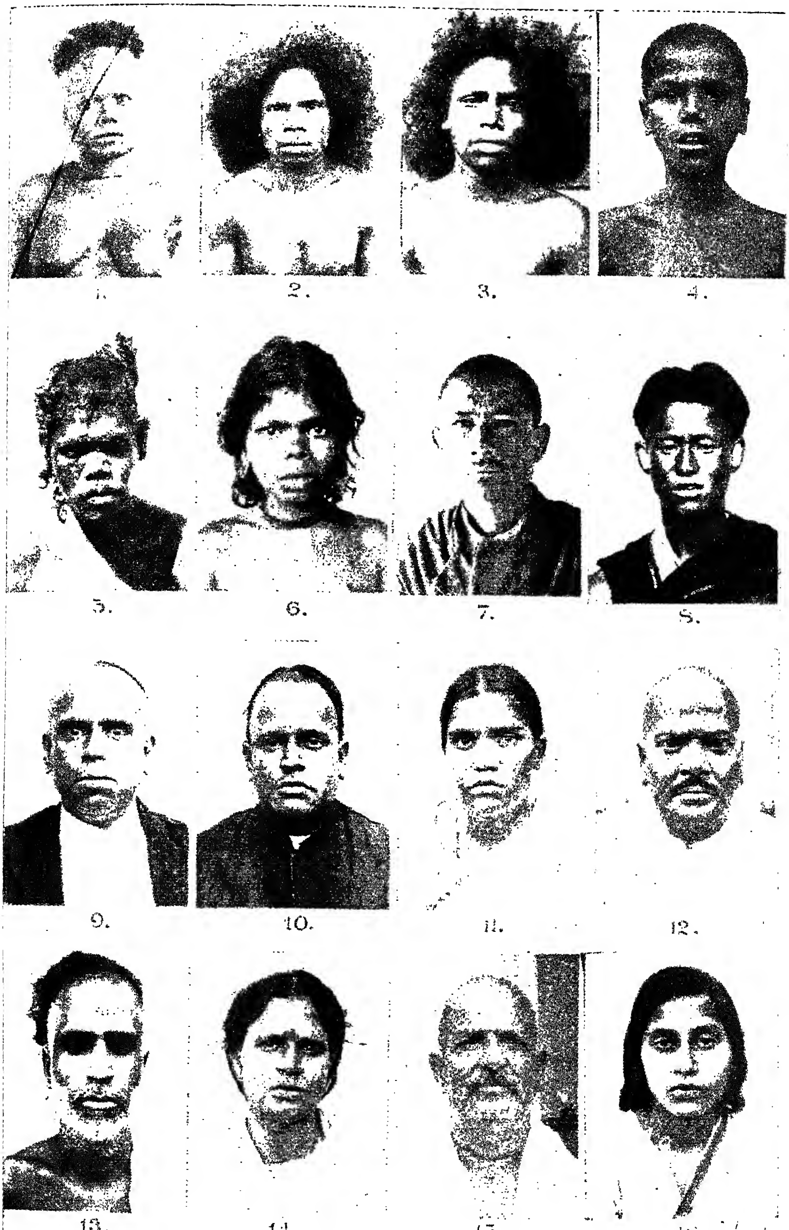
FIG. 14.—Nair lady of Cochin.

FIG. 15.—Behari Brahmin of Patna.

FIG. 16.—Bengali Kayastha lady of Calcutta.

Figures 1, 2, 5, 7, 8, 9, 10, 11 are reproduced from the *Census of India*, I, pt. 3, 1935, by kind permission of the Home Department of the Government of India.

GUHA : *Racial Ethnology of India.* PLATE VIII.



EXPLANATION OF PLATE IX.

Oriental Type.

FIG. 1.—Kho of Chitral (N.-W.F.P.).
FIG. 2.—Bania of Rajputana.
FIG. 3.—Chatri from the Punjab.
FIG. 4.—Brahmin lady of Maharastra.

Alpo-Dinaric Type.

FIG. 5.—Kathi from Kathiawar.
FIG. 6.—Bania from Guzrat.
FIG. 7.—Parsi lady of Ahmedabad.
FIG. 8.—Kanarese Brahmin of Mysore.
FIG. 9.—Baghel Rajput from Rewa.
FIG. 10.—Bengali Brahmin of Calcutta.
FIG. 11.—Bengali Vaidya lady of Calcutta.
FIG. 12.—Bengali Kayastha of Calcutta.

Proto-Nordic Type.

FIG. 13.—Red Kaffir from Rambur (N.-W.F.P.).
FIG. 14.—Khalash from Rambur (N.-W.F.P.).
FIG. 15.—Kho from Chitral (N.-W.F.P.).
FIG. 16.—Pathan from Bijaur (N.-W.F.P.).

Figures 4, 5, 11, 13–16 are reproduced from the *Census of India*, I, pt. 3, 1935, by kind permission of the Home Department of the Government of India.

GUHA : *Racial Ethnology of India.* PLATE IX.

AGRICULTURE AND ANIMAL HUSBANDRY IN INDIA.

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CONTENTS.

INTRODUCTION.

In attempting to describe the main outlines of Indian agriculture it has to be remembered that one is dealing with the agriculture of a sub-continent with a wide range of physical and climatological conditions as evidenced by the fact that there is hardly any cultivated crop of the temperate, sub-temperate and tropical zones, which is not grown, or which cannot be grown, in some part of it. Moreover it is characteristic of the agriculture of a large portion of the country that the summer annuals of temperate climates are grown during winter and more truly tropical crops during summer. In quite important areas also the climate is so modified by altitude and aspect that crops of temperate climates are found in unexpected latitudes.

The population of India is 338 million. The total area of culturable land is about 450 million acres excluding a forest area

of 83 million acres, and the total gross cropped area sown each year approximates to 285 million acres. As might be expected, the character of the cropping is mainly determined by population and here it has to be borne in mind that the animal population of the country is approximately 310 million head of which 208 million are cattle and 97 million sheep and goats. It is therefore no surprise to find that the total area under cereal and pulse crops of all kinds is no less than 244 million acres since these are the crops that are required for the maintenance of human and animal populations. Other food crops include the following :—

	Million acres.
Sugar	4·0
Tea	0·8
Coffee	0·2
Condiments and Spices ..	2·0
Fruits and Vegetables, including root crops	4·5
TOTAL	11·5

All the above figures include the Indian States but exclude Burma which has recently been separated from India. On balance India (apart from Burma) is a food-importing country, its average imports of rice from Burma and elsewhere amounting to approximately 2·2 million tons per annum. Viewed as a single economic unit which it was until very recently and which it still is to a very great extent, India *cum* Burma exports approximately 1·9 million tons of food grains. It should be added that the two principal cereal crops—wheat and rice—are, from the cultivator's point of view, largely commercial crops, for it is estimated that 55 per cent. of the wheat produced enters the general trade of the country, 45 per cent. being consumed in the villages of production. Of the commercial crops the most important are cotton (25 million acres), jute and hemp (3 million acres) amongst the fibres ; groundnuts 8 million acres, linseed 3½ million acres and rape and mustard 6 million acres amongst oilseeds ; tobacco 1¼ million acres. In Appendix I will be found a table showing the total area in India including Indian States and Burma for those crops for which separate statistics are maintained but for very obvious reasons many of the minor crops have been grouped, for even a complete list of individual crops would make a volume of considerable size.

The other dominating economic factor in Indian agriculture, which re-inforces the effect of dense population, is the smallness of the holdings and their fragmented character. Generally speaking, Indian agriculture is typical peasant agriculture, the number of landless agricultural labourers being relatively small and the holdings being largely worked by the peasant and his family. Additional labour is required at certain times but a considerable proportion of this is provided by the village itself. Despite the relatively large number of animals kept, mixed farming in the European sense of the word has been little developed. The bullock is the principal

working animal though male buffaloes are also used to an appreciable extent and the greater part of the transport is also done by bullocks. Cows are maintained for the production of working bullocks as much as for milk, which in some parts of the country is largely supplied by the she-buffalo.

The dominant climatological factor in Indian agriculture is the monsoon and it is the characteristic of the greater part of the country that most of the rainfall occurs between the months of June and October, *i.e.*, in the hot part of the year, the winter being comparatively dry.

Not only is the cropping and system of agriculture dominated by the character of the monsoon, but the Indian Budget has frequently been described as a gamble in rain. The greater part of the Indo-Gangetic Plain and the whole of the head of the Peninsula are served by the main monsoon lasting from June to October. The average rainfall for the whole of India during these months is approximately 40 inches, the actual for different belts ranging from about 15 (or less) to 50 inches with some special areas with much higher and much lower precipitation. The general characteristic of the cold weather is a rainfall of 2 to 4 inches between December and March. Storms occur, mainly in North-West India, in April and May but make no serious contribution to the useful rainfall. Monsoon or *kharif* crops, as they are known in India, are produced during the period of greatest rainfall, the most important being rice, the millets, maize, a great variety of summer pulses, cotton, jute and groundnuts. This is also the principal growing period of sugarcane which occupies the land a full year. In the greater part of India the cold weather or *rabi* crops such as wheat, barley, linseed, rape and mustard are sown in October-November and harvested from March to May. These crops depend very largely on the moisture which has been conserved from the previous monsoon period supplemented by such cold-weather rain as occurs and by irrigation. In the south of India, including the greater part of the Madras Presidency and large portions of the two great States of Hyderabad and Mysore, other climatic conditions prevail. Not only are temperatures higher and conditions more truly tropical, especially on the west coast, but the bulk of the rainfall is received in what is the dry cold weather in the greater part of India, *viz.*, October to February. In these areas also the alternations of *kharif* and *rabi* crops are practically non-existent and the only crops grown are of the character of those grown in Northern India during the monsoon period. In South India, rice and millets are important food crops while long-staple cotton and groundnuts are the most important cash crops.

Irrigation.

It would be impossible for the existing cultivated area in the greater part of India to maintain its population at the present

standard of living were crops entirely dependent on rainfall. This is supplemented by irrigation and it is a commonplace that India is the greatest irrigation country in the world. Of the total cultivated area of 280 million acres no less than 60 million acres are annually irrigated on the average from one source or another. Of this area 30 million acres are irrigated from canals, 15 million from wells and 15 million from tanks, streams and other sources.

The degree to which different areas are dependent on irrigation varies considerably. The best known amongst the most modern Indian canal systems are those of the Punjab and Sind canal colonies where rainfall is insufficient to mature any crop without irrigation and where land has literally been reclaimed from the desert and converted into fertile arable cultivation. Sind indeed is practically a rainless area and there are many parallels between its agriculture and that of Egypt. As we travel south-east we reach that portion of the Punjab and the great tract of the United Provinces where canal irrigation supplements natural rainfall, permitting of an extension of the *kharif* or summer season crop, or permitting of earlier sowing (which enables plants to develop well before the heavy rains begin) and supplementing the scanty winter rainfall to which reference has already been made. Briefly it may be said that irrigation permits of at least the doubling of the yield of the winter crops and in most areas sugarcane cultivation would be impossible without it.

A word may be said about irrigation from wells as the total area irrigated from these annually is so large. Undoubtedly many of the wells are small, many of them yielding not more than 800 gallons per hour or thereabouts, so that even a comparatively light irrigation means something like 60 hours work per acre. The greater part of the water-lifting is done by bullocks though, where the wells are larger, small oil engines and centrifugal pumps are by no means uncommon. The usual water lifts are the Persian wheel and its various adaptations and the typical Indian *mhote* or *charsa* which is traditionally a leather bucket hauled by a rope over a pulley and drawn by bullocks walking down a slope. This also has many modifications.

In many parts of India, for example in Bihar and also in the Bombay-Deccan, the United Provinces and the Central Provinces, irrigation from tanks and small lakes is of quite an important character. Some of these works amount to minor canals fed by storage reservoirs on small rivers or by barrages at the necks of mountainous catchment areas. Others are of a more domestic character but all contribute to the same end, supplementing inadequate rainfall. The traditional skill in the management of some of these small water supplies is perhaps seen at its best in mountain rice cultivation where a small hill stream is successfully trained to feed successive terraces covering several hill sides with a range of elevation of perhaps a thousand feet or more.

SOILS.

Four main soil types can be recognized in India, *viz.* : (1) the Red soils derived from rocks of the Archæan system which characterize Madras, Mysore and the south-east of Bombay and extend through the east of Hyderabad and the Central Provinces to Orissa, Chota Nagpur and the south of Bengal. (2) The black cotton or *regur* soils which over-lie the Deccan trap and cover the greater part of Bombay, Berar and the western parts of the Central Provinces and Hyderabad with extensions into Central India and Bundelkhand. The Madras *regur* soils, though less typical, are also important. (3) The great alluvial plains, agriculturally the most important tract in India as well as the most extensive, mainly the Indo-Gangetic Plain embracing Sind, northern Rajputana, most of the Punjab, the plains of the United Provinces, most of Bihar and Bengal and half of Assam. (4) The laterite soils which form a belt round the Peninsula and extend through East Bengal into Assam and Burma.

The great alluvial plains are characterized by ease of cultivation and rapid response to irrigation and manuring. Broadly speaking there are few soils in the world more suited to intensive agriculture so long as the water supply is assured. The other soils are less tractable and call for greater skill in management and are less adapted to small holdings; of these the *regur* soils are the most valuable.

AGRICULTURAL IMPLEMENTS.

As has already been said, practically all cultivation is done by draught bullocks and the capacity of these animals varies from district to district. The best types in common use are capable of handling what would be considered light single-horse implements in Europe. Reference has also been made to the importance of bullocks in drawing water from wells and in those tracts where the sugarcane is converted into *gur* (or jaggery) and not sold to modern sugar factories, bullocks are also used for crushing the sugarcane to extract the juice. Now simple three-roller iron mills are in vogue throughout the country though examples are still found of the giant pestle and mortar made of stone or wood which was the original form. Cultivating implements are few and simple. In the alluvial areas a simple wooden plough with an iron or steel point for soil stirring is the main requirement and is supplemented by a heavy wooden beam in the middle which serves the combined purpose of roller, clod crusher and soil compacter. With these two simple implements the cultivator of Northern India is able to carry out soil-moisture conserving operations with a precision which dry-farming experts of other countries might well envy. But these implements make an excessive demand on the limited bullock power and are not equally efficient for all purposes. In consequence the small iron plough has become increasingly popular during the

last quarter of a century and the number of them now in use in India runs into hundreds of thousands. Whilst the sale of such implements has been held up by the fall in prices of agricultural produce, the annual issues are still large. A good indication that these implements are in regular use is afforded by the number of spare parts sold. Originally imported and subsequently made by Indian firms these simple ploughs are now being turned out in large numbers in many parts of the country by small implement-makers. Other implements which in various areas have become important are several simple types of harrow and cultivator which are mainly of value in permitting timely work on the land and the intercultivation of crops in brief intervals between the monsoon downpours. Though on the whole the Indian peasant's time is far from fully employed both he and his bullocks often find difficulty in getting through their work at important periods of the season.

Manures and Manuring.

As regards manures and manuring, it must be admitted that India is backward. Despite the maintenance of a very large number of cattle, India is short of farm manure partly because a good deal of the cattle dung is burnt and partly because the use of litter is rare. Slowly the value of composting is being appreciated and the steady propaganda carried on by Agricultural Departments is doing something to remedy the marked deficiency in organic matter which characterizes Indian soils. In certain tracts the use of green manure is well known; in others green-leaf manure is common. Oil-cakes are used as manure in many areas, particularly castor cake which is produced in quite large quantities, as castor oil is an important lubricant for home use and is also exported in substantial amounts. The total quantity of ammonium sulphate and sodium nitrate used in India as manure now amounts to about 60,000 tons per annum, imports of potash manures amount to about 4,000 tons and phosphatic manures to about 14,000 tons. In addition, quite important quantities of phosphatic manures are produced and used in the country. Naturally the planting industries are amongst the most important users of concentrated fertilizers but the use of ammonium sulphate and oil-cakes for the more valuable staple crops and vegetables is steadily increasing though there has been an undoubted check due to the fall in prices of all agricultural commodities since 1929.

Principal Crops.

Brief mention may now be made of a few of the principal crops themselves. The rice crop (Plate X) is *facile princeps* since the total area in India and Burma is no less than 83 million acres annually when sowing conditions are moderately favourable or about 70 million acres in India alone. Rice is the principal food crop in Bengal, Bihar, Orissa, Burma, the

Rice

Central Provinces and Madras whilst in the United Provinces it is of equal importance with wheat. The total annual production of India and Burma is of the order of 32 million tons. The number of varieties is great as would be expected from the very wide range of the crop and the different conditions under which it is produced. The highest yields are obtained where the transplanting of seedlings into previously prepared puddled beds is the custom but in most provinces there is a substantial area under broadcast rice also. So far as India proper is concerned, rice is only a commercial crop to a limited extent, there being a small export of high quality rice from Bengal to the United Kingdom and Europe and from Madras to Ceylon. Burma of course is the world's greatest rice exporter and India imports annually from Burma anything up to 2 million tons of rice, mainly of the coarser kinds, to supplement internal production. In Bengal and Eastern India generally, rice is only irrigated to a very limited extent. In Madras, on the other hand, 8 million acres out of a total of 12 million acres are irrigated, the yield being correspondingly higher. Much work has been done on the improvement of rice crop by various Agricultural Departments, supplemented in recent years by the efforts of the Imperial Council of Agricultural Research and the total area under improved strains in India and Burma now amounts to 3·3 million acres.

Wheat

This is the second cereal in order of importance in Indian agriculture, the normal area being 35 million acres and production of the order of 9½ to 10 million tons. The principal wheat-producing provinces are the Punjab, the United Provinces and Sind, in all of which wheat is an irrigated crop. The Central Provinces comes next with the substantial area of 3½ million acres, mainly unirrigated, so that yields are relatively low. Up to ten years ago India was quite an important wheat-exporting country, export during the war period having reached as much as 1·7 million tons in a single year. Latterly exports have been less important and during the period of depressed wheat prices since 1930 have been non-existent until recently. During 1936-37 exports have been resumed and amounted to about quarter of a million tons and there are prospects of a larger total being reached during 1937-38. Wheat is grown by the Indian peasant partly as a cash crop and partly for his own food. The recent wheat marketing survey showed that approximately 45 per cent. of the wheat was used in the villages of production and 55 per cent. entered the general trade of the country. India has quite an important reserve of producing capacity and as there is every likelihood of production in North-West India and Sind responding to any permanent improvement in prices, the export of wheat from India may again become important. This crop was one of the first to receive attention from both the Imperial Department of Agriculture and the Provincial Agricultural Departments with the result that the area under improved wheats now exceeds 7

million acres of which about half is in the Punjab, about 2½ million acres in the United Provinces and over half a million acres in the Central Provinces. It is also satisfactory to note that the greater part of this large area is under half a dozen well-known improved varieties which may be mentioned Punjab 8A, Pusa 12 and Pusa 4, and the rust-resistant *sharbati* wheats of the Central Provinces. Of the total wheat area in India no less than 12·8 million acres are irrigated.

The next great group of food crops to be mentioned is the millets, the most important of these being the great millet, *Androposon sorghum* (vernacular, *juar* or *cholam*) which occupies annually about 35 million acres, the second in importance being the bulrush millet, *bajra* (*Pennisetum typhoideum*) which occupies annually an area of about 18 million acres, the total annual area under all millets being of the order of 63 million acres. *Juar* is essentially a monsoon crop in the greater part of India and the large area is due almost as much to its importance as a fodder crop as to its common use as a foodstuff in villages. *Bajra* also is essentially a village food-crop though there are substantial imports of it into some towns for use by the labouring population. The millets are generally recognized to have higher food values than rice. Plant breeding work for the improvement of these cereals is of more recent origin than that on rice and wheat but comparatively rapid progress has been made and the area under improved strains is now estimated to be 1,91,000 acres. It should be added that the great millet (*Juar*) is also grown on quite substantial scale as a special fodder crop for cutting green for the use of both milch and draught animals.

Pulses

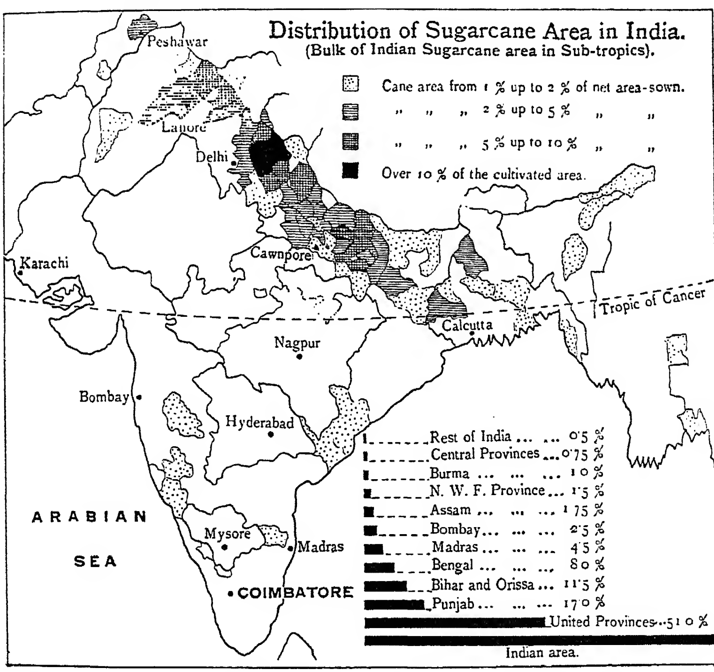
This very important group of crops accounts for practically 50 million acres annually and is trebly important to Indian agriculture. In the first place, they form the backbone of many rotations and it is due to the skilful use of leguminous crops that the present standard of fertility has been maintained in many parts of India with a minimum of manure. Their importance as foodstuffs in a predominantly vegetarian population needs no emphasis and they make an important contribution to the concentrated food supply for animals. The variety of pulse crops produced in India is very great and space will only permit mention of a few of the principal groups. One of the most important is the pigeon pea *Cajanus indicus* (vernacular *arhar* or *tur*) which is of interest in that it is grown in admixture (either broadcast or in lines) with either *juar* or cotton. Most varieties take longer to grow than either a millet or cotton and in the former case the greater part of the growth occurs after the millet crop is harvested. *Arhar dal* is one of the most important foodstuffs of the country-side. Of other *kharif* or monsoon pulses may be mentioned the following :—

Gram (*Cicer arietinum*), Peas, Lentils, and many species of *Phaseolus*.

An extremely important winter pulse is gram which occupies annually some 15 million to 17 million acres and is specially important in the United Provinces, the Punjab and the Central Provinces. It is often grown in combination with wheat, especially on the black soils of Central India and the Central Provinces. The total area under improved types of gram is now estimated to have reached 2,81,000 acres. Of recent years much more work has been done on the improvement of pulse crops but this is only just beginning to yield results so that the systematic introduction of improved strains is yet in its early stage.

Sugarcane

This crop forms a convenient link between the food crops and the commercial crops of India. The present area under sugarcane exceeds 4 million acres—an increase of practically 40 per cent. during the last ten years. This is due to a variety of causes of which the principal one is the establishment of a large modern sugar industry consequent on the grant

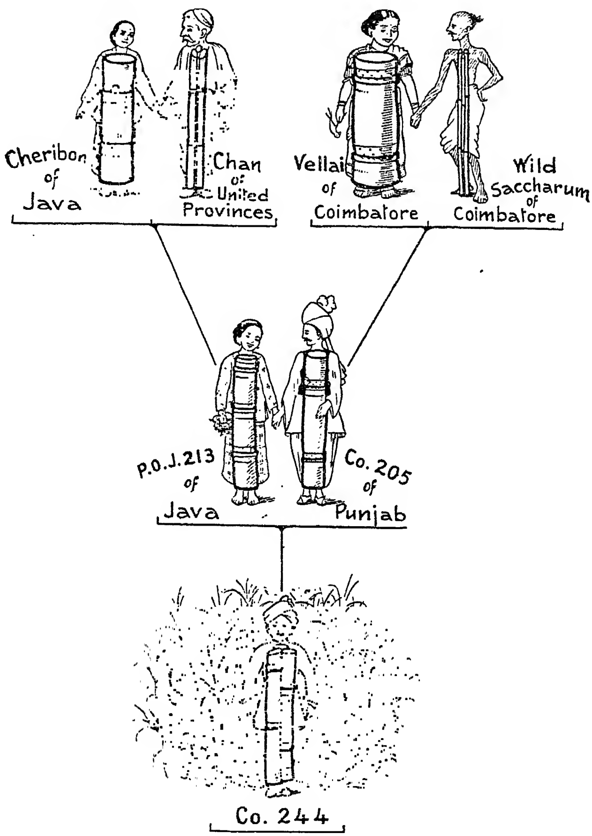


TEXT-FIG. 1.—Coimbatore (in tropical India) has successfully bred improved seedlings for the main sugarcane tracts of Sub-tropical North India.

Modified from 'Agriculture and Livestock in India', V, pt. 6, (1935).

of fiscal protection, white sugar production in 1936-37 having reached the level of 1,100,000 tons. An equally important cause is the spread into general cultivation of improved varieties of sugar-

cane which have made sugarcane production much more profitable, even with comparatively low prices for *gur* or jaggery which is the form in which two-thirds of the sugarcane is consumed. The principal sugarcane growing provinces are the United Provinces, Bihar, the Punjab, Bengal, Madras and the Bombay-Deccan and of the 137 modern sugar factories now operating 67 are situated in the United Provinces and 35 in Bihar. It is one of the special features of sugarcane growing in India that nearly nine-tenths of it is situated



TEXT-FIG. 2.—Family Tree of a simple Coimbatore Hybrid.
Reproduced from 'Agriculture and Livestock in India', VI, pt. 6, (1936).

in the semi-temperate zone and only a comparatively small proportion is grown in tropical India. The result is that the varieties of sugarcane which are most successful in India are quite different from the tropical, or 'noble', canes familiar elsewhere. The canes now in general cultivation are mainly the productions of the Coimbatore Sugarcane Breeding Station and are hybrids which

include in their parentage the wild cane (*Saccharum spontaneum*), some of the older Indian varieties and some of the best varieties of the tropics. Only in very limited parts of India have direct introductions from other parts of the world proved an economic success. The productions of the Coimbatore Sugarcane Breeding Station now occupy approximately 3 million acres.

Cotton

Of the purely commercial crops of India pride of place must be given to cotton which occupies an area of about 25 to 27 million acres with a gross production of some 6½ million bales. Of this usually 2½ million bales are consumed in Indian mills, and about 3½ million bales are exported, the remainder being used for miscellaneous domestic purposes in villages without entering into the trade of the country. India is second only to the United States amongst the cotton-producing countries of the world. Unlike America, there is no single cotton-growing belt and cotton of several distinct species and more commercial varieties is grown in the different provinces under quite varying conditions. Approximately 30 per cent. of the total cotton area in India is in the Bombay Presidency which in itself exemplifies the diversity of conditions, there being no less than four cotton-growing tracts. Grouped according to short staple and long staple and ranged under familiar trade names the annual production of cotton in India is approximately as follows :—

The Indian Cotton Crop of 1936-37 *classified according to length of staple.*

(In thousand bales of 400 lbs. each.)

Long-staple (over 1 inch).	
Punjab-American	47
Medium-staple, A. (1 inch).	
Sind-Sudhar	100
Others	47
Medium-staple, B. (7/8″ to 31/32″).	
Surti	170
Cambodia	183
Hyderabad Gaoroni	141
Tinnevellies	160
Kumpta-Dharwar	100
Punjab-American	797
Sind-American	197
Others	260
Short-staple, A. (11/16″ to 27/32″).	
Central India / Malvi and Nimari	306
C.P. Oomras	107
Dholleras-Wagad	234
Broach-Kanvi	133
Others	189
Short-staple, B. (18/32″ to 21/32″).	
Khandesh Oomras	245
C.P. Oomras	666
Hyderabad Oomras	319
Dholleras-Mattheo	287
Burmas	113
Others	49
Short-staple, C. (17/32″ and below).	
Bengals-U.P.	175
,, Sind	221
,, Punjab	1,026
Others	135
GRAND TOTAL	6,307

The most compact single block of cotton cultivation is that centring on the Central Provinces, Berar, Khandesh and Central India with extensions into Rajputana, the United Provinces and even the Punjab, where the main cotton produced is of short-staple types including the various forms of *Gossypium neglectum*. Of such types approximately one million bales are consumed in the country, the remainder being exported largely to Japan. India also exports substantial quantities to the United Kingdom and the Continent. The long-staple cottons of Gujerat and part of Kathiawar, of the southern part of the Bombay Presidency and a large portion of Madras consist of the various forms of *Gossypium herbaceum*, differing in numerous important characters but closely related. The third group consists of American types (*Gossypium hirsutum*) which are the result of the acclimatization of imported types and now occupy 3½ million acres including Punjab-American, Sind-American, Dharwar Upland and Madras Cambodia cotton. These are all types of much longer staple, suitable for higher counts and are in substantial demand by Indian mills, the surplus finding a ready export market. Work on the improvement of the cotton crop has been systematic and sustained, especially since the establishment of the Indian Central Cotton Committee in 1921. The total area under improved strains now in general cultivation is 3·8 million acres. For more detailed information as to what has been achieved in the improvement of the cotton crop of India reference is invited to a separate publication by the Indian Central Cotton Committee. It is sufficient to say here that during the last 15 years a radical change in the balance between short staple and long staple cottons in India has occurred. In the typically short-staple tracts better-yielding and hardier types, which are more profitable to the grower, have been introduced and whilst in such areas as the Punjab and Sind definite new areas of long-staple cottons have been established, in the older long-staple cotton areas like Bombay and Madras the local cottons have been improved in staple and uniformity by the application of modern plant-breeding methods. The cotton crop is also unique in that for the last 15 years there has been maintained in India a Technological Research Laboratory under the Indian Central Cotton Committee. Here has been carried out systematic work on the fundamental characters which determine the quality and spinning value of cotton and also the systematic testing of new strains of cotton for Agricultural Departments in order that the most profitable types, from every point of view may be brought into cultivation.

Jute

Jute, India's other great fibre crop, is an Indian monopoly and is produced mainly in the province of Bengal and the adjoining portions of Assam and Bihar. The present area under jute cultivation is 2·18 million acres, with an estimated production of some 7 million bales. This is far below the potential producing capacity of the jute

growing districts, since, owing to the falling off in the world demand consequent on general trade depression but also due to no small extent to the development of bulk methods of grain handling, the world demand for jute fibre has fallen off. In 1926 the jute area was only just below 4 million acres and production was estimated at 12 million bales. Work for the agricultural improvement of the jute crop has mainly been devoted to the establishment of higher-yielding varieties of quality not inferior to the standard trade types. Such work has been markedly successful, the present area under improved strains being approximately 1·1 million acres. Recently an Indian Central Jute Committee, on the lines of the Indian Central Cotton Committee and financed by an annual grant of five lakhs per annum from the Government of India, has been established for the further improvement of this important agricultural industry.

Hemp

Though far less important than the two fibres previously mentioned, the two Indian hemps are of no small importance in the aggregate. Sunn hemp (*Crotalaria juncea*), the more important of the two, occupies annually an area of about 600,000 acres. Exports, which have recovered markedly during the last three years, now amount to about 33,000 tons per annum. The other variety of hemp (*Hibiscus cannabinus*), sometimes known as Roselle hemp and otherwise as Bimlipatam jute, is of more importance for local use than for world trade. Both kinds are used largely for the manufacture of ropes and twine in India. Sunn hemp is of importance from another point of view in that it is the most generally successful of the green manure crops.

Oilseeds

The oilseeds form an extremely important group of cash crops in India. The most important of them is the groundnut crop which now occupies $7\frac{1}{4}$ million acres with a production of nearly 3 million tons. This is of special interest as in many parts of India groundnut is a comparatively recent production and the extension of the area under this crop has been extremely steady, having been practically uninterrupted since 1924 when the area was less than 3 million acres. India is a great exporter of groundnuts and also a substantial exporter of groundnut oil and of groundnut cake but approximately 1,300,000 tons out of the average gross production of 2,500,000 tons (nuts in shell) is consumed in the country. Groundnut oil is an important edible oil over a large part of India; it is also the principal raw material used in the hydrogenated oil factories which have grown up in India during the last few years for the production of various vegetable substitutes for *ghi*. Work on the improvement of the groundnut crop has been in progress in Madras for some years and has recently been intensified as a result of a grant by the Agricultural Research Council. Successful work has also been carried out in the Bombay Presidency on the

substitution of a disease-resistant type for the older variety which was frequently decimated by the well-known Tikka disease.

Next in importance comes the group of Brassicac of which the most important commercial types are the rape and mustard of Northern India. These are produced mainly for home consumption. The annual area approximates to 6 million acres and production to a million tons. Exports in recent years have rarely reached the 100,000 tons mark. The oil is extremely important for food purposes whilst the cake is an important cattle food. Most of the rape and mustard produced in India is crushed in small village crushers, though an appreciable amount is handled in modern factories. Work on the improvement of this group of oilseeds is comparatively recent.

Linseed

The annual area under this crop is about $3\frac{1}{2}$ million acres, the most important provinces being the Central Provinces, the United Provinces and Bihar. The annual production is of the order of 400,000 to 450,000 tons though there is reason to believe that this has been considerably under-estimated in the past. This crop is largely grown in admixture with other crops which renders an estimate of area and yield particularly difficult. On the average rather more than half the linseed produced in India is exported mainly to the United Kingdom and the Continent of Europe, the remainder being crushed in the country. Extensive research on linseed has been carried out at the Imperial Agricultural Research Institute for many years. The Indian linseeds have been completely classified, the various types isolated and the hybrids between the bold large-seeded type of the black soil areas and the small-seeded prolific type of the Gangetic Plain have been produced. Several of the hybrids have a high oil content and a medium size seed. The introduction of improved types into general cultivation has recently been undertaken.

Plantation crops

The three principal plantation crops in India are tea, coffee and rubber. The area under tea in India is approximately 820,000 acres, of which three-quarters lies in Assam and the adjoining districts of Northern Bengal, the greater part of the remainder being in South India mainly the Nilgiris. Production of tea in India is roundly 400 million pounds per annum. As is well known, tea production all over the world has been excessive and an international scheme for the regulation of the export of tea has been into operation since April, 1933. Export quotas are allotted by the International Tea Committee as a percentage of the standard year 1929-30. The current figure is $87\frac{1}{2}$ per cent. In tea we have an example of a very highly organized planting industry maintaining its own scientific departments—in Northern India by the Indian Tea Association and in South India by the Tea Section of the United Planters' Association of Southern India. As a result, much valuable work has been done and a consistent policy followed over a long

series of years to the great good of the industry. It is impossible to summarize this work in any reasonable space. Of recent years the work in scientific departments of the two Associations has been mainly devoted to a study of the fundamental reasons underlying cultural and manurial methods.

Coffee

Coffee production in India is mainly limited to a part of the Madras Presidency, the State of Mysore and the small province of Coorg with small areas in the Travancore and Cochin States, the total area actually under coffee being rather over 180,000 acres. The annual total production of cured coffee is about 34 million pounds and exports in recent years have averaged 8,700 tons. India is one of the most important producers of fine mild coffee in the world. Of the total number of nearly 7,000 plantations reported over 3,000 were small plantations of between 5 and 10 acres covering about 20,000 acres in all. Coffee research is provided for at the Coffee Research Station at Balehonnur in the Mysore State which is financed jointly by the Mysore Government and the United Planters' Association of Southern India. The recently established Indian Coffee Cess Committee is mainly concerned with propaganda to increase the consumption of Indian coffee both in India and abroad and works in London through the Indian Coffee Market Expansion Board which is presided over by the Indian Trade Commissioner. The Committee has also, in co-operation with the Imperial Council of Agricultural Research, inaugurated research on the quality of coffee.

Rubber

The total area under rubber in India and Burma is approximately 226,000 acres of which 175,000 acres was tapped. About 47 per cent. of the total area is in Burma, 43 per cent. in Travancore, the remainder being in Madras, Cochin, Coorg and Mysore. Rubber exports are limited by the International Scheme for the regulation of rubber production and export.

Fruit

Statistics of fruit production in India are markedly deficient, especially as no small part of the total is accounted for by roadside trees and unrecorded small groves which are of special value to the rural population. But so far as can be ascertained the area under fruit is about $2\frac{1}{2}$ million acres. Fruit research has received a marked stimulus during the last few years by grants from the Imperial Council of Agricultural Research which is financially supporting a co-ordinated scheme of work. This embraces a hill fruit research station in the Kumaon Hills of the United Provinces for work on apples and other temperate climate fruits, one for mangoes and plains fruit at Sabour in Bihar, a plains fruit research station in the Madras Presidency, a special scheme of work on citrus fruits at Nagpur with special reference to the santra type of orange, another at Lyallpur with special reference to the Malta type of orange and a scheme of experimental work on the cold storage of

fruit at Poona in the Bombay Presidency where tests are carried out for all provinces.

ANIMAL HUSBANDRY.

Reference has already been made to the large number of live-stock maintained in India but unfortunately it has to be recorded that many of these are of extremely poor quality. Nevertheless the livestock industries in India are worth annually to the country no less than *Rs.1,300* crores made up somewhat as follows :—

	Crores of Rs.
Cattle labour in agriculture	408·00
Labour for purposes other than agriculture	127·00
Dairy products	540·00
Manures	180·00
Other products	30·00
Living animals exported (inland trade omitted)	0·24
TOTAL ..	1,285·24

The approximate composition of India's livestock population (including Indian States and Burma), as shown at the 1935 census was as follows :—

Bulls and Bullocks	66	millions.
Cows	53	,,
Young Stock	49	,,
Total (Ox tribe) ..	168	,,
Male Buffaloes	7	,,
Female Buffaloes	22	,,
Young Buffaloes	18	,,
Total Buffaloes ..	47	,,
Total Bovines ..	215	,,
Sheep	43	,,
Goats	53	,,
Horses and Ponies	2	,,
Mules and Donkeys	2	,,
Camels	1	,,
GRAND TOTAL ..	316	,,

Diseases. The first and greatest problem in regard to this huge population of domestic animals is the control and prevention of epidemic disease and this object has had the unremitting attention of the Imperial Institute of Veterinary Research and of provincial Civil Veterinary Departments during the last 25 years—and with very striking results. The deaths from contagious diseases in the provinces of India and Burma had

been reduced from 4,00,000 in 1925-26 to 3,00,000 in 1932-33, 2,64,000 in 1934-35 and 2,50,000 in 1935-36. Deaths from rinderpest have fallen from 2,78,000 in 1925-26 to 1,41,000 in 1934-35 and 1,38,000 in 1935-36. The latest discoveries of the Muktesar Research Institute, two methods of vaccination with a goat virus of fixed virulence, have provided an inexpensive means of conferring lasting immunity against rinderpest and, given organization and determination, there is no apparent reason why most at least of the country should not be cleared of this disease. Systematic control measures are also in operation against the other cattle plagues, *viz.*, Hæmorrhagic septicæmia, black quarter and anthrax, the necessary vaccines and *sera* being supplied by the Central Veterinary Institute. It has also been possible in recent years to devote attention to other diseases of domestic animals which though less fatal are of possibly greater economic importance than the plagues referred to above. The strengthening of the staff at the Imperial Veterinary Research Institute (including the setting up there of separate sections of pathology, bacteriology, serology, helminthology, protozoology and entomology, each under a specialist), coupled with the appointment in each province of a disease investigation officer who maintains liaison with the Central Institute has made possible a great advance. More attention has also been paid in recent years to animal nutrition both from the economic standpoint and in connection with the maintenance of health, a fully equipped animal nutrition laboratory has recently been established at Izatnagar near Bareilly for this purpose, attached to the Izatnagar Branch of the Central Veterinary Research Institute. The work carried on by Dr. Warth at Bangalore on the nutrition of Indian Cattle and the composition of Indian foodstuffs has been continued and developed. Experimental work of a similar nature, but not overlapping with the Izatnagar programme, is being carried out at several centres including Lyallpur, Coimbatore and Dacca by provincial Agricultural Departments. The question of grass land improvement has also received attention recently.

Breeding

Breeding work for the actual improvement of cattle has followed three main lines in those provinces where most attention has been devoted to it. These are: (1) The breeding and supply of suitable stud bulls; (2) the establishment of definite breeding areas where intensive work is carried out under premium bulls schemes or other suitable methods, and (3) the systematic castration of scrub bulls.

The number of approved bulls at stud in 1935-36 was approximately 10,000 an advance of 13% on the previous year but still far too small. During 1936-37 as the result of the initiative and example of His Excellency the Viceroy a great stimulus to cattle improvement has been given. It has recently been decided to set up provincial livestock improvement Boards (or Associations) which will continue to raise funds and advise on their application.

Pedigree herds of most of the more important and valuable Indian breeds of cattle (Plates XI and XII) have now been established and the following may be mentioned.

I. Milch Breeds.

Breed.	Herds maintained at
Sahiwal ..	.. New Delhi (I.A.R.I.), Manjahra (U.P.), Lyallpur, Ferozepur, Montgomery Dist., Nagpur, and Ranchi.
Tharparker ..	.. Ranchi, Patna, and Karnal.
Hariana ..	.. Karnal, Hissar, Madhuri, Khund, and Ellichpur.
Scindi ..	.. Allahabad, Bangalore, Hosur, Trivandrum, Poona and Mirpur Khas.
Gir ..	.. Bombay and Bangalore.
Kankrej ..	.. Chharodi and Baroda (Bombay Presidency).
Ongole ..	.. Guntur.
Murrah Buffaloes	.. Punjab, United Provinces and Sind.

II. Draught.

Kangyam ..	.. Hosur and Palayakottai.
Hariana ..	.. Hissar.
Dhanni ..	.. Punjab.
Amrat Mahal	.. Ajjampur (Mysore).
Khairgarh ..	.. Hempur (U.P.).
Ponwar ..	.. Hempur (U.P.).
Malvi ..	.. Central Indian States and C.P.
Gaolao ..	.. Central Provinces.
Bhagnari ..	.. Sind.
Deoni ..	.. Hingoli.

Another important step was taken during 1936-37 in the setting up of Breed Committees and the starting of a scheme for the central registration of pedigree animals of the principal milch breeds of India, *viz.*, Sahiwal, Scindi, Tharparkar, Hariana, Kankrej, Gir, Ongole, Murrah Buffaloes.

The experience of recent years has emphasized the special value of these indigenous Indian breeds. Not only are they hardy and disease-resistant but under proper conditions of feeding and management the best have reached a very satisfactory figure of milk production especially when allowance is made for the systematically high percentage of fat.

Dairying

A central dairy institute and farm mainly for the purpose of instruction in the principles of dairy-farming and European dairy methods has been maintained by the Central Government at Bangalore for many years. Funds have recently been allotted for the enlargement and development of this institute and of a branch at Anand in Gujarat to include a larger amount of experimental work and research on milk and milk products. A great immediate problem is that of a better supply of milk to Indian cities. This can only really be solved by taking cows out of the cities and sending in milk from suitable country areas. This calls for immediate experimental work on

processing and transport which will be taken up at the enlarged Imperial Dairy Institute. A report on the steps to be taken to develop Indian dairying has been made by Dr. N. C. Wright, Director of the Hannah Dairy Research Institute, Ayr, Scotland who toured through India on behalf of the Imperial Council of Agricultural Research in 1936-37 to study the problem.

In this brief note it has been impossible to give any adequate picture of Agriculture and Animal Husbandry in India but those who are interested are invited to consult the annual publication of that name issued by the Imperial Council of Agricultural Research and the annual report of that body.

Appendix I.

Area (in thousands of acres) under cultivation for principal crops.

	1930-31.	1931-32.	1932-33.	1933-34.	1934-35.	1935-36.
Rice .	82,846	84,374	82,882	83,423	82,507	81,841
Wheat .	32,189	33,803	32,976	36,077	34,490	33,605
Sugarcane .	2,801	2,971	3.317	3,311	3,481	4,003
Tea .	803	806	809	818	826	826
Cotton .	23,812	23,722	22,483	24,137	23,972	25,994
Jute .	3,492	1,862	2,143	2,517	2,670	2,181
Linseed .	3,009	3,309	3,299	3,261	3,410	3,402
Rape and Mustard	6,632	6,220	6,094	6,034	5,338	5,268
Sesamum	5,618	5,639	6,256	6,307	5,230	5,633
Castor seed	1,457	1,583	1,617	1,534	1,448	1,447
Groundnut	6,579	5,489	7,409	8,226	5,766	5,784
Coffee .	160	172	176	183	185	188
Rubber	192	184	180	224	225	228
Other crops .	83,596	85,422	83,361	82,662	81,815	79,835

Appendix II.

Yield of principal crops.

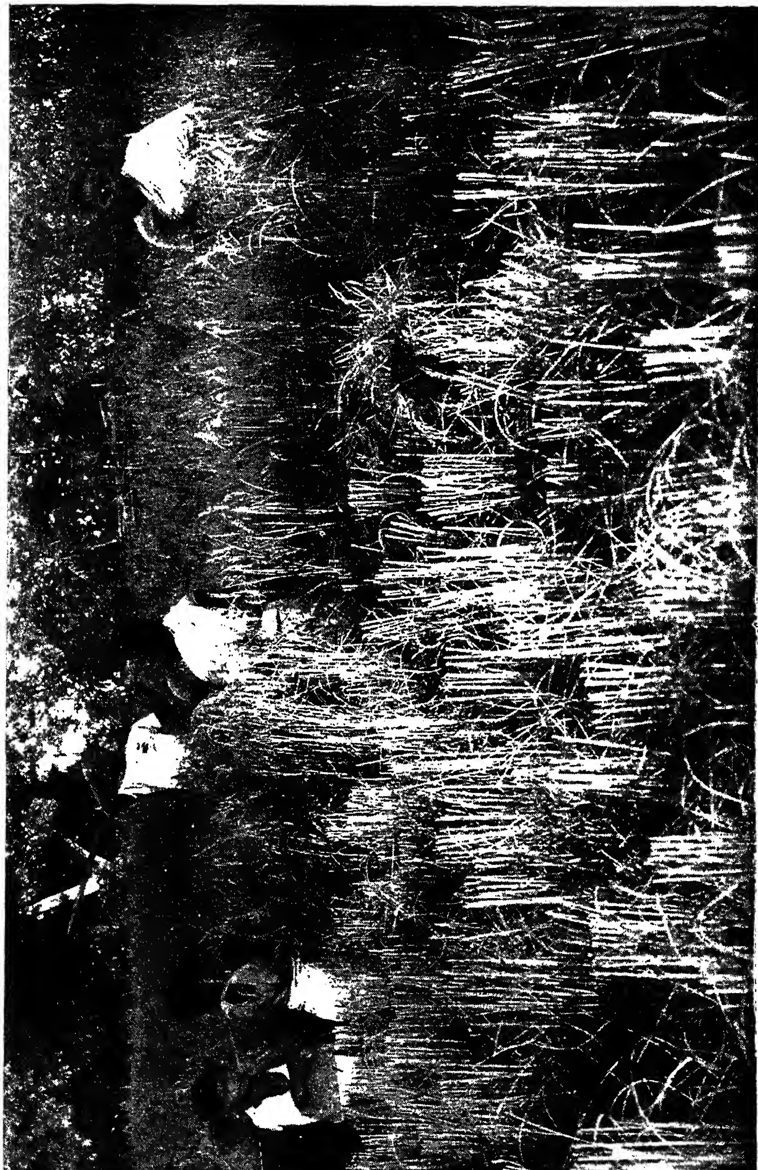
Rice	'000 tons	32,198	33,001	31,114	30,907	30,238	27,902
Wheat	,,	9,306	9,024	9,455	9,370	9,729	9,426
Gur	..	3,228	3,975	4,676	4,896	5,140	5,903
Tea	'000 lbs.	391,080	394,083	433,669	383,674	400,095	396,660
Cotton	'000 bales	5,226	4,007	4,657	5,108	4,857	5,963
Jute	,,	11,205	5,542	7,072	7,987	8,500	7,215
Linseed	'000 tons	377	416	406	376	420	384
Rape and Mustard	,,		1,025	1,042	943	900	954
Sesamum	,,	526	476	551	541	406	461
Castor-seed	,,	120	146	151	143	105	119
Groundnut	,,	2,766	2,268	2,997	3,330	1,884	2,228
Coffee	'000 lbs.	32,973	33,613	33,037	34,601	32,744	41,162
Rubber	,,	24,351	20,117	6,381	12,915	37,156	48,545
Other Crops	'000 tons	18,368	17,793	17,653	16,974	18,052	17,925

EXPLANATION OF PLATE X.

The Assamese cultivator and his family harvesting paddy.

Reproduced from *Agriculture and Livestock in India*, Vol. VII, pt. 4, (1937).

BURT : *Agriculture and Animal Husbandry in India.* PLATE X.



EXPLANATION OF PLATE XI.

Bull No. 539 Rajad ; Born 12-2-1930 ; Sire—Raja ; Dam—Adami ; Dam's best lactation—7,850 lb. ; Weight on 21-12-1935—1,100 lb. (Photographed on 13-12-1935).

Reproduced from *Agriculture and Livestock* in India, Vol. VI, pt. 6, (1936).

BURT: *Agriculture and Animal Husbandry in India.* PLATE XI.

EXPLANATION OF PLATE XII.

Early maturity bull Nala No. 602 ; Born—25-2-1932 ; Sire—Narayan ; Dam—Lalagi ; Dam's best lactation—7,425 lb. ; Weight on 21-12-1935—1,164 lb. (Photographed on 13-12-1935).

Reproduced from *Agriculture and Livestock in India*, Vol. VI, pt. 6, (1936).

BURT : *Agriculture and Animal Husbandry in India.* PLATE XII.

AN OUTLINE OF ARCHÆOLOGY IN INDIA.

By

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CONTENTS.

Of all the field sciences included in this volume archæology dealing with the vicissitudes of man's culture throughout the ages is the last. In a country of the size and antiquity of India the sum total of man's endeavours throughout the millennia of its existence must baffle any attempt to summarize the main features of the story of India's culture through the ages which is here sketched within the limits of available space.

Stone Age

The story of India's culture begins in Peninsular India when palæolithic man wielded rough hewn stone implements in the valleys of Narmada, Godavari and other river systems of the South. The oldest finds to which a date can be assigned on geological (but not on archæological) grounds is the find of a 'boucher' at Bhutra in the Narsinghpur District of the Central Provinces. Bones of extinct mammals were found associated with this rough stone implement. Another important find of a slightly more advanced technique is an agate chip found in the bed of the Godavari at Mungi in the Ahmednagar District opposite Paithan in the Nizam's Dominions. Various other finds in the Nizam's Dominions, Mysore, Shevaroy hills and the Jawadi hills and in the ravine beds in the Madras Presidency testify to the existence and the habitat and wanderings of palæolithic man. The neolithic stage is more widespread and embraces finds of flints in Upper Sind and in the

Sohan valley in the Northern Punjab and the Assam hills in the north-east, while South India again continues to be prominent on the map of neolithic India. Systematic investigation of the typical neolithic sites of the advanced stage has yet to be undertaken and may reveal the steps by which man recorded the tremendous advance which is a feature of the next or chalcolithic stage. It is noteworthy that in South India the iron age succeeds closely in the wake of the neolithic culture without any intervening copper or bronze age, which is of so great importance in North-Western India.

Mohenjodaro and the Indus Culture

Fifteen years ago it appeared as if the historic civilization of India descended upon an aboriginal population just introduced to metal tools, if not still wielding implements and weapons fashioned from stone. The hoary civilization of the valleys of the Nile and Euphrates hardly seemed to have any counterpart in the valleys of the Indus and the Ganges, although the physical conditions in the latter appeared to be as conducive of rearing a robust population and as extensive and advanced a civilization as any in the ancient world. The province of Sind, which, but for a number of Buddhist establishments barely 1,500 years old, was then perhaps the most unimportant part of India to the archæologist, has now been brought into its own as one containing the richest and most important sites in the country. Mohenjodaro, the premier ancient city of Sind, is not only the oldest known but also the best preserved site in India, which, more than any other discovery in Indian archæology has stimulated the interest of scientists and scholars. The origin of every aspect of Indian art and culture has now to be traced to Mohenjodaro times. Thus the famous limestone statuette of a bearded man draped in an upper garment with trefoil embroidery (Plate XIII) is the earliest attempt in Indian sculpture. The art of the seal-cutter and jeweller, the conch-worker and lapidary, the skill of the town-planner and house-designer and various other advances in the technical arts indicate the high level of the Indus valley civilization. Investigations in other parts of Sind, Baluchistan, the Punjab and Kathiawar have brought to light a wealth of other smaller sites, which well illustrate the scope and extent of this ancient Indian culture. Some trial excavations at Nal and other places in Baluchistan and recent work by the American expedition at Chanhudaro have thrown more light on certain other aspects and phases of this culture of the Indus valley. In the Punjab the city of Harappa, more extensive but less well-preserved than Mohenjodaro has yielded important material, particularly in the shape of a cemetery. It is undoubted that if work is extended to other sites in Punjab and Sind they will yield further valuable material for the reconstruction of this remarkable civilization. In the North-West Frontier Province the discovery of certain terra cottas from the lower strata of certain mounds near Charsadda is

being ascribed to the same early period, and if this opinion is confirmed by further researches, it will undoubtedly prove the strong root which the civilization had taken throughout the Indus basin.

Copper Age in North India

The continuation of the ancient Indian culture from the Indus valley to the Gangetic plains has not yet been clearly traced, but there can be no doubt that the next few years will see the links between the prehistoric and historic cultures of India firmly established. In Northern India the age of copper and bronze seems to have continued for a sufficiently long period, but apart from implements, which have been brought to light by chance finds, no systematic excavation has yet been attempted. The most common implements are shouldered celts, harpoons, axes, spear heads and swords, which have been discovered at various places in the United Provinces. The most important and biggest hoard of prehistoric metal implements and objects came from Gungeria of the Balagarh District of the Central Provinces. It contained as many as 421 specimens of almost pure metal and 102 laminæ of silver, exhibiting an amazing variety of implements. More work if done at a suitable site in the United or Central Provinces is likely to establish connection between these copper age finds and the Indus civilization.

Gap in India's History

The correlation of the early Vedic and Brahmanic literature which is localized with any archæological remains in the Punjab and United Provinces has not yet been established and the entire epoch from about 2,500 B.C. to 500 B.C. is a strange gap in Indian cultural continuity. The immigration of the Aryans into India and their colonization and gradual settlement over the whole expanse of Northern India has undoubtedly to be fitted somewhere into this period, but archæology has so far been unable to settle the chronology of the principal events and occurrences referred to in the vast Vedic and epic literature.

One group of monuments, which was long believed to belong to the Vedic age, is the so-called Vedic burial cemetery at Lauriya Nandangarh in Bihar. Recent work at this site has proved that the mounds at this place do not go back to any high antiquity, although some very interesting and extensive structures showing a novel type of architecture have been found. Rajgir, the ancient capital of Magadha, is another place reputed to have existed before the time of Buddha, but beyond the city walls of crude cyclopean masonry, which may date anywhere from the 7th century to the 3rd century B.C., no definite relics of an early age have been discovered.

Dawn of Historic Age

When light again emerges on Indian history the Indo-Aryan civilization has already worn itself out and a protest against the orthodox Brahmanical religion had already made itself felt in the shape of Buddhism and Jainism. The earlier monuments of these

faiths pertain to the third and second centuries B.C. and it was the royal patronage of the Mauryan emperors Aśoka and Daśaratha and that of the Kings of Orissa such as Kharavela that enabled these protestant faiths to erect monuments of outstanding importance. From this time onwards the main currents of Indian history are quite clear and the systematic field work of the last thirty years has enabled archæologists to study the tangible remains of the different periods and in the various historic tracts of India.

Mauryan Art and Architecture

Before the discovery of the Indus civilization, the monuments of the Mauryan period, then the earliest known in India, provide a great stumbling block to the students of architecture. With the distant background provided by the Indus Valley remains, it is not now difficult to conceive of the achievements of Mauryan artists as the products of an age-long tradition enlivened by fresh contact with the Perso-Greek world. The results of regular excavations at Pāṭaliputra (roughly modern Patna) and Sarnath, as also the number of artistic objects brought to light in course of the sewage operations at Patna, leave no doubt about the flourishing state of arts in the Mauryan age. In one respect, viz., the manufacture of terra cotta figurines, there seems to have been maintained a remarkably high level of technique and there is little doubt that in other respects similar will be found to be the case. What is indisputable, however, is the fact that stone carving and stone architecture was for the first time attempted in the Mauryan period, and in some of the examples of the latter class, timber prototypes are postulated. The caves at Barabar in Gaya District, excavated for the Ājīvika sect of ascetics in the time of Daśaratha, the grandson of the famous Buddhist Emperor Aśoka, are an outstanding example of the cave architecture of this period. In sculpture, the capitals, which Aśoka provided for his pillars, the best example of which is the exquisite Sarnath capital (Plate XIV), represent the art of the Imperial court, which does not seem to have much affected the trend of popular art. The latter is represented by certain statues from Patna, Besnagar (Central India) and Parkham (near Muttra) which are characterized by a feeling of volume and mass, though in point of sculptural modelling it represents a primitive conception.

Bharhut and Śuṅga Art

In the time of the Śuṅgas, who came into power during the 2nd century B.C., Indian art made further strides towards development, and the Buddhist stūpa at Bharhut (Central India) which is the most remarkable monument of this period, illustrates its simple but expressive character. The fragments of the railing around the Bharhut stūpa, which are now kept in the Indian Museum, Calcutta, show how the artists have succeeded in narrating the stories of Buddha's life and his former births, both human and animal, with a naive beauty all its own, in spite of technical shortcomings in modelling and perspective. Among the series depicted in the

panels, special mention may be made of the dream of Māyā, Buddha's mother, the royal processions of the kings of Rajgir and Śrāvastī visiting the Buddha, the acquisition of the Jetavana park by the merchant Anāthapiṇḍaka, who had the whole ground strewn with gold coins, and the former lives of Buddha as a monkey, a deer or an elephant. Besides these several other reliefs on the railing pillars depicting demi-gods and *yakshas*, male and female, which no doubt occupied much space in popular imagination are noteworthy.

Sāñchī and Mathurā

The magnificent Buddhist remains at Sāñchī in the Bhopal State are the best preserved in the series of early Buddhist monuments in India. Here the main stūpa, which was probably built by the Mauryan Emperor Aśoka, was later faced with stone and surrounded by a stone railing pierced by four gateways, one on each cardinal point, which are elaborately decorated with figure sculptures and bas-reliefs illustrative of Buddha's life or the *jātaka* legends. The art of Sāñchī shows a still further development in technical skill and more conventionality and in itself covers a century-long development which brings us to the beginning of the Christian era. Another great centre of art, which commenced its activity at this period but which was to attain phenomenal development in the succeeding centuries, is Mathurā. Here the abundance of stone in the neighbourhood seems to have been availed of by all the religious persuasions alike, and some of the earliest Brahmanical and Jaina images in India were manufactured at this centre. In fact, Mathurā is one of the most important and prolific centres of sculpture throughout Northern India.

The Graeco-Buddhist School of Gandhāra

The domination of the Graeco-Bactrian, Scythian and Parthian rulers in the North-west of India introduced a flood of new artistic ideas based on the Hellenistic ideals of beauty. This gave rise to a new school in the North-west of India popularly known as the Graeco-Buddhist school of Gandhāra which rose in the 1st-2nd centuries of the Christian era. One innovation introduced by the Gandhāra school was the image of the Buddha, which was not hitherto attempted by the sculptors of the indigenous school, the presence of the Buddha being always indicated by means of symbolic representations. The Museums at Lahore and Peshawar and, to a less extent, the Indian Museum, Calcutta, bear witness to the intense devotion of the Buddhists of North-west India and the prolific activity of the sculptors trained in Hellenistic traditions. The impact of these new forces that were making themselves felt in the North-west reached Mathurā along with the Kushān domination in 2nd century A.D., and in due course extended further inland both to the East and South. Some of the Gandhāra motifs are to be found slightly modified in the products of the Buddhist school in the Krishna Valley as at Amarāvatī and Nāgārjunikoṇḍa in the

Guntur District of the Madras Presidency. On the whole, however, the Hellenistic element in Indian art was completely absorbed by the 4th century A.D. when under the stimulus of the Gupta Emperors, Indian art reached its classical age.

Western India Caves

In Western India the growth of Hinduism has left few other monuments except the rock cut caves which offer fascinating material for the student of architecture. The geological formation of Western India with its deep strata of volcanic trap rock is responsible for the concentration of more than 80 per cent. of India's cave temples in this part of the country. The earliest among the series are the groups at Bhaja and Karla near Poona, the Chaitya Hall at the latter place being one of the most impressive of the series. Both in the decoration of the façades as well as the interior arrangements, these groups of caves at Nasik, Kanheri and other places in the Bombay Presidency offer much admirable material to the student. Their dates are fixed by a large number of inscriptions of the Āndhra kings and the Western Kshatrapas occurring in them who lived in the 1st and 2nd centuries A.D. Some of these continued to be inhabited till the Gupta epoch and the world renowned caves of Ajanta in the Nizam's Dominions preserve the best known examples of Indian paintings which are unparalleled in the East.

Gupta and Mediæval Art

The rise of the Gupta dynasty in Northern India in the 4th century A.D. ushered in the golden age of Indian art in every branch of fine arts. Indian genius had this time fully assimilated all that was best in the foreign influences that were brought to bear during the previous centuries and a thoughtful synthesis resulted in which the best impulses of Indian art were given full expression. The keynote of the work of this period was a broad intellectualism and a balance between spiritual thought and material expression. The best sculptures of this period have been found at Sarnath, Mathurā and Deogarh in the United Provinces, while examples of terra cotta and minor arts have been found in practically all the excavations in North India. In the field of religion, the steady ascendency of the Brahmanical faith over the Buddhist schools began in the Gupta period and gradually gained rapid ground particularly in Western and Southern India. In Eastern India, however, Buddhism continued to hold its ground in Bihar and Bengal until it was finally ousted by the onrush of Islamic invasion in the 12th century A.D.

Brahmanical temples in Western and Southern India

In Western India, the caves at Badami in the Bijapur District, the capital of the Chālukya kings, the magnificent Kailāsa temple at Ellora in the Nizam's Dominions built in the 8th century, and the Elephanta caves near Bombay with some of the most powerful and expressive sculptures

in India, are outstanding examples of the enthusiastic activity of the followers of the revived Brahmanical religion. In Southern India the seven Pagodas at Mahabalipuram and the temples at Conjeevaram, both near Madras, show the spirit and vigour of art under the Pallava kings. The seven Pagodas, although cut out of living rock, are perfect examples of structural temples, and the huge bas-reliefs representing the animated scenes of the descent of the Ganges (Plate XV) are wonderful specimens of Pallava art. The foundations of South Indian art and architecture laid by the Pallavas were later to provide the superstructure for the great architectural efforts under the Cholas and still later under the Vijayanagara empire. The great examples of Indian temple architecture are provided by the temples in the South Indian or Dravidian style at such centres as Tanjore, Chidambaram, Madura, Trichinopoly and Ramesvaram.

Later Buddhism in Eastern India

In Eastern India, the great Buddhist centre from which much of the cultural expansion of Indian Buddhism in Northern and Eastern countries emanated was Nālandā. An idea of the splendour and eminence of this place can now be had from the excavated stūpas (Plate XVI) and monasteries and the antiquities, particularly the magnificent collection of bronzes, recovered from the ruins. The remains at Paharpur in Bengal consisting of a gigantic central temple surrounded by a very extensive monastery (Plate XVII) afford a glimpse of Bengal of the pre-Muslim epoch, of which no extant remains have survived. In fact, field archæology has had a much wider scope in the plains of Northern India where very few remains of architecture, dating before the Muslim invasion, have survived.

Styles of temple architecture

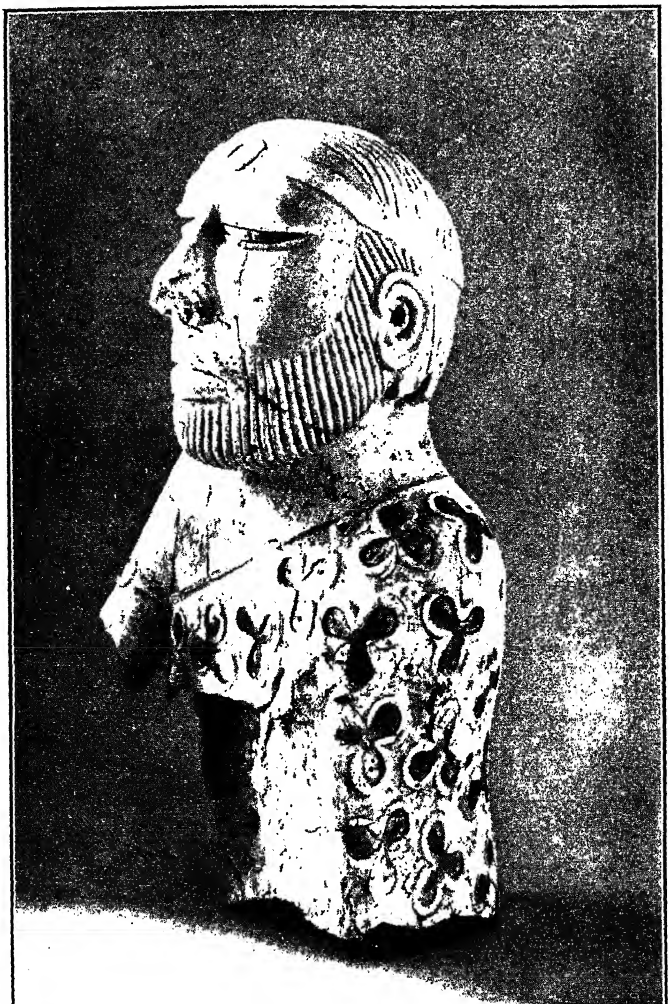
In Central India a number of local schools of art register a steady decline of the ideals and achievements of the Gupta times. Among architectural ideas, the most prominent is the emergence of the *śikhara* type of temple with its elongated spire and sculptural decoration as compared with the simple flat-roofed temple of the Gupta period with its restraint and dignity. Several regional types of temples can be studied, one being located at Khajuraho in Central India and another and a more magnificent one at Bhuvanesvara in Orissa. The temples in Gujerat and Rajputana, among which those dedicated to the Jaina faith are predominant, form an important regional type, while in the Deccan and Carnatic there is a widely prevalent style of architecture coming down from the times of the Chālukya kings of the Deccan. In Mysore the temples at Belur and Somanathpur form prominent examples of the local style of architecture which is known after the Hoysala rulers.

Islamic Monuments

The emergence of the forces of Islam in Northern India in the 12th century put an end to the indigenous artistic and sculptural activities, but in the earlier products of Islamic monuments such as the Great Mosque built by Qutb-ud-din at Delhi, it is evident that the dominant features of the art of the conquered Hindus made themselves felt in the monuments of the alien faith. Hereafter Islamic architecture manifested itself into several local styles, each characterized by local peculiarities in which the indigenous element was not slow to assert itself. Thus the splendour and effeminate beauty of the Gujerat carving is a prominent feature of the mosques at Ahmedabad, while in Bengal the monuments at Gaur and Pandua reflect in no uncertain manner the langour and decadence of the late Pāla work in Bengal. Some of the local styles such as those at Mandu in Malwa and particularly at Bijapur strike an original and strong note. In and around Delhi and Agra the advent of the Moghuls ushered in an era of architectural magnificence, of which the tomb of Humayun at Delhi, the splendid remains at Fatehpur Sikri built by Akbar and the great Taj Mahal are the most magnificent examples.

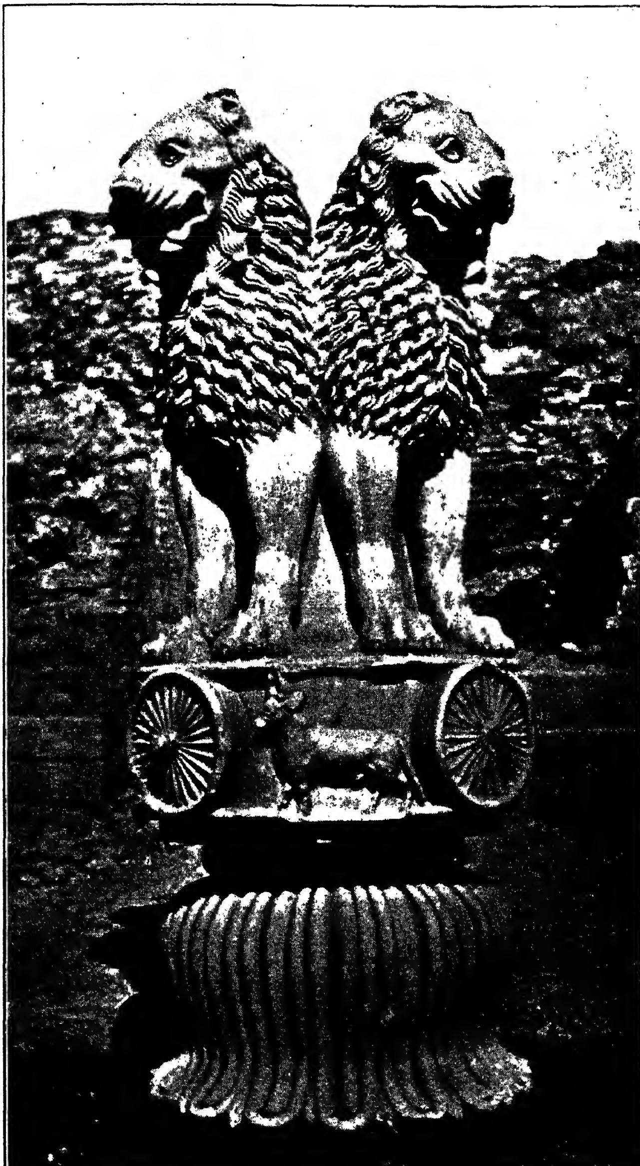
EXPLANATION OF PLATE XIII.

Limestone statuette from Mohenjodaro. This is the only piece of sculpture recovered from the Indus Valley excavations. It represents a bearded man, probably of aristocratic stock as is evident from the upper garment which he is wearing. This garment or shawl is embroidered with trefoil leaves which are picked out in ochre red. The attempt shows the primitive state of the sculptor's art in the Indus Valley as contrasted with the contemporary sculpture of Egypt and Sumer and the advance in other technical arts such as that of the potter and seal-cutter in India itself.



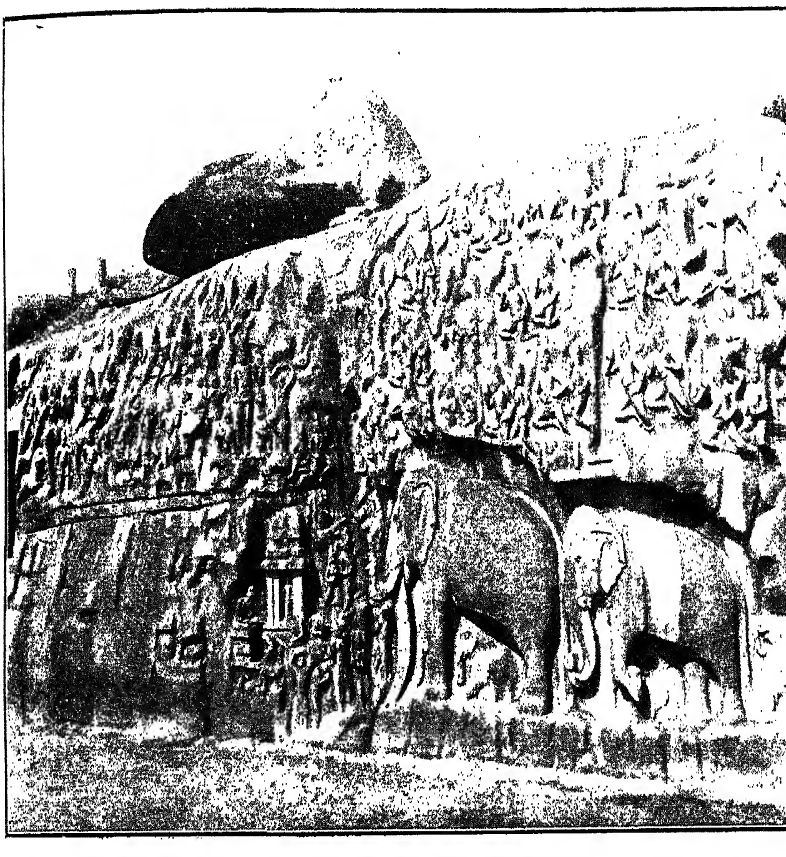
EXPLANATION OF PLATE XIV.

Polished stone capital found at Sarnath in course of excavation. It originally crowned the monolithic pillar which Aśoka, the great Buddhist Emperor, set up at the place where the great founder of the Buddhist religion preached his first sermon. The excellent polish and the technical perfection of this piece, particularly the lions crowning the piece and the animals on the abacus, entitle this piece to be considered among the masterpieces of Indian art. The animals on the abacus are an elephant, a bull, a horse and a lion, which are interpreted as symbolizing the conception, birth, migration and enlightenment of the Buddha.



EXPLANATION OF PLATE XV.

Rock carvings at Mahabalipuram, popularly known as the Seven Pagodas near Madras. These wonderful specimens of Pallava art are referred to the 6th-7th century A.D. The present relief represents the scene of the descent of the Ganges which was brought down from heaven through the efforts of King Bhagīratha. A number of animated scenes with men and animals are depicted on either side of the river which itself is shown as a shallow depression through which actually water passed from the top of the rock.



EXPLANATION OF PLATE XVI.

A view of the great temple at Nālandā, which with its numerous temples and monasteries was the biggest centre of Buddhism from 6th to 11th century A.D. The main temple, originally constructed about the 5th or 6th century A.D., underwent no less than six renovations, all of which have been brought to light by a careful excavation of the stupendous mass. The towers at the corners have been decorated with figures in stucco. The finds of stone and particularly bronze images, besides inscriptions, seals, etc., at Nālandā constitute a record and have been very valuable for the reconstruction of the history of art and religion in Eastern India.

EXPLANATION OF PLATE XVII.

The great temple at Paharpur in the Rajshahi District of North Bengal. The excavations conducted here for about a decade have brought to light the remains of a magnificent temple surrounded by the largest single monastery in India with 180 rooms. The plan of the central temple with its multiple terraces, recessed angles and friezes of terra cotta plaques is unique in India but has been widely followed in Burma, Siam and Java. In the basement a number of stone sculptures representing Brahmanical deities and the stories of the exploits of Kṛishṇa—the earliest in Bengal—have been found. The establishment was founded by Dharmapāla of the Pāla dynasty in the 8th century and continued till the 12th century A.D.

HIT : *Archæology in India.* PLATE XVII.

INDIAN SCIENCE CONGRESS ASSOCIATION:
SILVER JUBILEE, 1938

The Progress of Science in India during The Past Twenty-five Years

Edited by

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Contents.

INTRODUCTION.

By

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CONTENTS.

I. PREFACE.

About the end of November 1936 the Executive Committee of the Indian Science Congress Association invited me to act as the general editor of a book entitled 'The Progress of Science in India during the past twenty-five years', which, together with some other publications [1] was to be issued in commemoration of the Silver Jubilee Session of the Congress. The Executive Committee had decided that the volume should consist of 16 chapters and had already issued invitations to a number of specialists in different parts of the country to contribute the various chapters. It was the intention of the Executive Committee of the Indian Science Congress Association to have the volume ready for the Silver Jubilee Session of the Indian Science Congress in January 1938, but this was found impossible.[2] It took some time to arrange various details such as the format of the publication, the size of the volume and the limits of the various chapters, and it was not till really in January 1937 that general instructions in regard to the contributions to the projected volume could be issued to the authors of the various chapters.

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[1] A volume entitled 'An Outline of the Field Sciences of India' under the editorship of Rai Bahadur Dr. S. L. Hora was published in November 1937.

[2] The manuscript for the last chapter was not received till after the middle of April, 1938.

Several difficulties have presented themselves as the work progressed; the most serious of these was in reference to the exact limits of the period of the review. The first session of the Indian Science Congress was held in Calcutta in January 1914 and the twenty-fifth meeting took place in January 1938. But this period does not correspond exactly to the twenty-five years during which the progress of Science was to be reviewed in the work under contemplation. As a result, the different contributors have dealt with the progress from 1910 or 1912 onwards to the close of 1937. In regard to the publication itself it may be noted that the number of chapters of the book has increased from 16 to 18, and as very few of the contributors found it possible to confine their accounts to the limit of 30 printed pages, as originally fixed for each chapter, the size of the volume has increased from the original estimate of 500 pages to about 800 pages. Since it was decided to allow the authors a free hand, they have dealt with their subjects according to their own ideas, and owing to the very limited time available it has not been possible to revise all the contributions together to arrange the treatment of the general matter, citation of literature and so forth on a uniform plan; this would, in most cases, have entailed the recasting of the contributions, and inordinately delayed the publication of the work. With a view to expediting the publication of the volume, the material for the different chapters was sent to the press as it was received from the contributors, and various chapters were arranged not in any definite sequence, but as they were ready for printing. While conscious of its shortcomings, I can only hope, with Virgil, that it will not be a case of '*Ibi omnis effus labor*', and that the volume will, at least, provide the basis for a more detailed and critical review of the progress of Science in India at some later date.

A work that covers in some 800 pages so vast a field as the progress of all sciences, both pure and applied, in India during the past twenty-five years is apt to be either a historical text-book or a series of essays. In neither instance can it be a full narrative of events, nor would it be possible within the limits of such a volume even to review adequately all the work that has been carried out. This publication may be described as a series of essays in so far as it attempts to analyze the developments in various sciences by workers in Universities, in scientific institutes, scientific departments of the Government of India and various Provincial Governments and other cognate agencies all over the country. It is also a historical text-book in so far as it briefly presents in a narrative and chronological form the advances in different sciences together with short accounts of the work carried out during the period in each of the different branches of Science. To describe such a sketch as the history of the progress of Science in India is, on the face of it, to be guilty of a misnomer. But apparently no other name suggested to the Executive Committee of the Indian Science

Congress Association would have served to describe briefly but concisely the development of Indian Science during this very momentous quarter of a century.

In the following pages I have tried to give a brief account of the organization and growth of English education in India, and traced the development of the scientific work in the country from about the beginning of the nineteenth century to the foundation of the Indian Science Congress Association in 1914. In a later section is given a brief survey of the main advances in different sciences as treated in Chapters II—XVIII of this book.

It is my pleasant duty to express my indebtedness to the General Secretaries of the Indian Science Congress Association, Dr. J. N. Mookerjee and Mr. W. D. West, for their kind help and advice at all times, and to the authors of the various chapters for their co-operation, which alone has made it possible to publish this volume in such a short time. I am also grateful to Sir Lewis Fermor, F.R.S., formerly Director, Geological Survey of India, for reading through the Introductory Chapter and making valuable suggestions; his recent reviews of the progress of Science in India have also made my task much lighter.

Messrs. K. N. Das and K. N. Bagchi of the Zoological Survey of India have helped materially in the preparation of the matter for the press. My thanks are also due to Messrs. P. Knight and N. A. Ellis of the Baptist Mission Press for advice in regard to technical details and for carrying out the work of printing so efficiently and expeditiously.

II. Organization and Growth of English Education in India.

To get a correct perspective of the conditions in the early years of the present century, when the Indian Science Congress was founded, it is essential to have at least a general idea of the earlier organization and growth of English education in India, and the following brief survey [1] will, it is hoped, serve this purpose.

The Board of Directors and the local officers of the East India Company in the early days of the British domination in India, while 'sympathetic towards attempts to revive Indian learning .... entertained no idea of introducing any system of education' into the country. In 1781, however, Warren Hastings established a *Madrasa* in Calcutta for the study of 'Muhammadan law and such

[1] The above account is based on Sharp and Richey '*Selections from the Educational Records of the Government of India*' (Calcutta, 1920–22), the admirable reviews of the progress of Education and the growth of Educational policy in India by Sir H. Verney Lovett in Chapters VI and XIX of Volume VI, The Indian Empire 1858–1918 of '*The Cambridge History of India*', (1932) and the chapter on Education in '*The Indian Year Book*, 1935-36', (Bombay, 1936).

other sciences as were taught in Muhammadan schools'. In 1792 Jonathan Duncan, Resident at Benares, obtained permission 'to establish a college in the holy city for the preservation and cultivation of the laws, literature and religion of the Hindus', for recovering and collecting books on 'the most ancient and valuable general learning and tradition now existing on perhaps any part of the globe'. Reference may also be made here to the schools started and maintained in the eighteenth century by Lutheran Missionaries in Southern India and by William Carey and other Baptist Missionaries at Serampore in Bengal.

The introduction of Western learning into the country in the earlier years, however, was due in Calcutta to the pioneer efforts of David Hare and Ram Mohan Roy, who in 1816 established at Calcutta a *Vidyalaya* (home of learning) for the 'tuition of sons of respectable Hindu parents in the English and Indian languages and in European and Asiatic science and literature'; its name was later changed to Hindu College, and finally in 1855 to Presidency College since when it has maintained its position as the premier teaching institution of Bengal. The great impetus to the introduction of Western learning, however, was due to the Christian Missionaries who founded a Missionary college at Serampore in 1818, the Wilson School at Bombay in 1834, and the Madras Christian College at Madras in 1837.

In connection with the renewal of the charter of the East India Company in 1813, section 43 of the Act 'empowered the government to expend not less than a lakh of rupees on the revival and encouragement of learning'. No real action, however, seems to have been taken in the matter though grants were given 'to two societies formed to promote vernacular education and improve indigenous schools'. In 1823, however, a 'Committee of Public Instruction' composed of civil servants was appointed to suggest measures for 'the better instruction of the people, and the introduction of useful knowledge, including the arts and sciences of Europe'. This Committee received the arrears of the grant in terms of the Act of 1813, and decided to spend it 'on the best means of improving the education of the more respectable members of Indian society especially those who make letters their profession'. With this end in view, they started a few schools for teaching English, English classes in certain Oriental colleges and made available by printing in Sanskrit, Persian and Arabic both original works and translations of some English books on Mathematics, etc. But the Committee soon found that there was an incessant and ever-increasing demand for the teaching of the English language, which could hardly be met by the means at its disposal. Faced with these difficulties, the Committee split into two parties, the older Orientalist and a younger English party. The former wanted to follow a policy of engrafting European education on the indigenous system, while the latter proposed to devote all

available funds to imparting 'through the medium the literary and scientific information necessary for a libe tion. Although for some time the knowledge so conv be confined to a limited circle, it would soon penetrate to the outer community through the channel of a new vernacular literature'. This doctrine became famous as 'the filtration theory'.

Following the policy laid down by Lord Bentinck in 1835, which was based mainly on Macaulay's famous minute,[1] the government, while observing neutrality in religious matters, decided to establish secondary schools and colleges in the country in which education was to be imparted through the medium of English, and instituted a policy of subsidizing private educational institutions by giving them grants-in-aid. Greater freedom of the press was established by Charles Metcalfe in 1836 and in 1837 English replaced Persian as the language of the law courts. In 1842, the Committee of Public Instruction was replaced by a Council of Education with a few non-official Indians as members. The most momentous step for encouraging English education in the country, however, was the dictum of Lord Hardinge's Government in 1844 that preference for public service would be given to candidates with a knowledge of the English language.

A further epoch in Indian educational history was marked by Sir Charles Wood's despatch in 1854, in which 'the old idea that education imparted to the higher classes would filter down to the lower classes was discarded', and the Government were required to create 'a properly articulated scheme of education, from the primary school to the university'. This resulted in the creation of Departments of Public Instruction in different provinces for the efficient inspection of all educational institutions, 'beginning with the humblest elementary institution and ending with the university'. These departments were under the Central Government but, in

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[1] The detailed minute by the Hon'ble T. B. Macaulay, dated 2nd February 1835, is published in the "Selections from Educational Records", Part I, 1781–1895, edited by H. Sharp, pp. 107–117 (Calcutta, 1920). The relevant part of the minute referred to above runs as follows :

> 'To sum up what I have said. I think it clear that we are not fettered by the Act of Parliament of 1813, that we are not fettered by any pledge expressed or implied, that we are free to employ our funds as we choose, that we ought to employ them in teaching what is best worth knowing, that English is better worth knowing than Sanscrit or Arabic, that the natives are desirous to be taught English, and are not desirous to be taught Sanscrit or Arabic, that neither as the languages of law nor as the languages of religion have the Sanscrit and Arabic any peculiar claim to our encouragement, that it is possible to make natives of this country thoroughly good English scholars, and that to this end our efforts ought to be directed'.
>
> '* * * * * We must at present do our best to form a class who may be interpreters between us and the millions whom we govern—a class of persons Indian in blood and colour, but English in tastes, in opinions, in morals and in intellect'.

1871, their control was transferred to the various Provincial Governments. The despatch also outlined a scheme for the foundation of a university system in the country and, as a result, three universities were founded at Calcutta, Bombay and Madras in 1857, while the Universities of Punjab and Allahabad were established in 1882 and 1887 respectively. All the five universities were of the affiliating type and their energies were directed mainly to examining the daily growing numbers of students who presented themselves for various examinations and degrees; they were not, therefore, in any way either centres of teaching or of research. Most of the schools and colleges in different parts of the country did not teach science, while the staffs of the few that did, had to devote their entire attention to teaching and could hardly be expected to play any part for the advancement of learning by original work.

To review the working of the universities Lord Curzon's Government appointed a Universities Commission in 1902, which resulted in the passing of the University Act of 1904. The objects of this Act were to tighten up control on the part of the Government over the universities and, in their turn, of universities over schools and colleges. The universities were further given the powers for granting recognition and inspecting schools and colleges under their jurisdiction, though the inspection of schools in actual practice was left to the officers of the Departments of Public Instruction. The main point of interest of this Act from the point of view of this summary, however, is that the universities were given permission to undertake direct teaching functions and, subject to Government sanction, could make appointments for this purpose; in practice their activities in this direction were, however, to be limited to post-graduate work and research.

The educational policy of the Government of India was reviewed in two important Government Resolutions, one of 1904 and the second of 1913. The Resolution of 1904 was very comprehensive in character and reviewed the state of education throughout the country in all its departments. It resulted in the next few years in the assignment by the Central Government to the Provinces of large grants mainly for higher, technical and elementary education. The Resolution of 1913 which followed the separation of education from the control of the Home Department of the Government of India to an independent Department of Education in 1910, advocated *inter alia* 'the establishment of additional but smaller universities of the teaching type; it reaffirmed the policy of reliance on private effort in secondary education; it recommended an increase in the salaries of teachers and an improvement in the amounts of grants-in-aid; and it insisted on proper attention being paid to the formation of character in the education given to scholars of all grades. It further discussed the desirability of imparting manual instruction and instruction in hygiene; the necessity for medical inspection; the provision

of facilities for research ; the need for the staffing of the girls' schools by women teachers and the expansion facilities for the training of teachers. The policy outlined in 1913 materially accelerated progress in the provinces, but the educational developments foreshadowed were in many cases delayed owing to the effects of the Great War[1].' As a result of this policy and the efforts of educationalists all over the country thirteen new universities, viz., Benares Hindu University, Mysore, Patna, Osmania, Aligarh Muslim University, Rangoon, Lucknow, Dacca, Delhi, Nagpur, Andhra, Agra and Annamali Universities were established in India between the years 1916 and 1929.

Finally reference may be made to the reports of the Calcutta University Commission published in 1921 and that of the Auxiliary Committee of the Indian Statutory Commission on Education in 1929 which reviewed in detail the position of universities and the growth of education in general in the country.

From the above it will be clear that scientific education in India started very late, for though arrangements for the teaching of some of the sciences were made in a few schools, colleges and special institutions like the medical and engineering colleges from 1855 onwards, this provision was hardly sufficient for the spread of scientific education in the vast continental area of India. After the passing of the University Act of 1904, various universities, however, were able to arrange for better facilities for the necessary teaching staff and requisite laboratories, etc., for the teaching of different sciences in the country, and the progress in all the sciences in India during the past quarter of a century has been remarkably rapid. Though there are some fundamental defects in regard to the arrangements for scientific education in the country, as detailed by Dr. Jenkins in Chapter II of this volume, one may hope that conditions will continue to improve and that the progress of Science will go hand-in-hand with the general progress of education.

III. Scientific Work up to the end of the Nineteenth Century.

(a) *Scientific work in ancient India.*

The contributions to Science by ancient India are to be discussed in a separate volume[2] to be published under the editorship

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[1] '*The Indian Year Book*, 1935–36,' p. 366 (Bombay, 1936).

[2] Professor Saha writes that the publication of this volume has been delayed owing to the contributions for all the chapters not having been received. Three articles dealing with (1) Ancient Indian Mathematics by Mr. Avadesh Narayan Singh of the Lucknow University, (2) Ancient Indian Astronomy by Dr. Gorakh Prasad of the Allahabad University, (3) Ancient Indian Chemistry by Prof. P. Neogi of the Presidency College, Calcutta, have been received, and it is hoped that as soon as the material for other chapters is received, it will be possible to publish the volume.

of Professor Meghnad Saha, F.R.S., and it is not necessary, therefore, to make more than a passing reference to the scientific work in Ancient India.

Fermor [1] has summed up the advances of Hindu Science as follows :—

'It must not be thought that during the whole of the several millennia between the early astronomical observations of the Babylonians and the introduction of modern science into India by Europeans, Asia has been scientifically asleep. The Hindus and the Arabs have also made their contributions. The Hindus in particular made advances in mathematical science following on the stimulus to intercourse with Europe resulting from Alexander's conquest. Amongst these mathematicians may be mentioned Bhaskara (c. A.D. 1120) for his contributions to algebraic notation. I have mentioned this name specially because it reappears now amongst modern Indian scientists in the person of the Director of the Nizamia Observatory at Hyderabad. All Hindu science in India may not date, however, from the introduction of Greek influence. For, in a recent paper read before our Society in 1934, Dr. S. L. Hora has shown that the ancient Hindus, as revealed in a passage in *Susruta-samhita* (c. 300 B.C.), had exact knowledge of the habitats of fishes and of the modes of their locomotion, and that Susruta's knowledge of the latter has been rediscovered only in the last few years by zoologists in America and England. It is known also that the Hindus had considerable knowledge of medicine and of chemistry as has been summarized for the latter in Sir P. C. Ray's 'History of Hindu Chemistry', published in 1902. Further researches by oriental scholars into old Sanskrit and Pali texts may bring to light knowledge of other branches of science possessed by the ancient Hindus. Reference may also be made to B. N. Seal's work on 'The Positive Sciences of the Ancient Hindus', London, 1913, in which claims are made on this subject that are not accepted in full by all. Dr. Baini Prasad's paper 'Some Pre-Linnaean Writers of Indian Zoology' gives information concerning the knowledge both of the Hindus and of the Moghals.'

'It seems likely, indeed, that when the full range of knowledge of the ancient Hindus in the realms of science and mathematics comes to be known, as far as this is possible, it may prove to be partly indigenous and pre-Greek and partly based on Greek influence.'

In his History of Sanskrit Literature Macdonell [2] remarked :—

'In Science, too, the debt of Europe to India has been considerable. There is, in the first place, the great fact that the Indians invented numerical figures, used all over the world. The influence which the decimal system of reckoning dependent on those figures has had not only on Mathematics, but also on the progress of civilization in general, can hardly be over-estimated. During the eighth and ninth centuries the Indians became the teachers in arithmetic and algebra of the Arabs, and through them of the nations of the West. Thus, though we call the latter science by an Arabic name, it is a gift we owe to India.'

'The history of the progress and civilization of that nation (the Hindu)', however, as Bose [3] remarked, 'closes with the end of the twelfth century. Every work that has the stamp of originality

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[1] Fermor, L. L.—*Year-Book of the Royal Asiatic Society of Bengal*, Vol. I, 1935, pp. 14, 15 (1936).

[2] Macdonell, A. A.—*A History of Sanskrit Literature*, p. 424 (1913).

[3] Bose, P. N.—*Centenary Review of the Asiatic Society of Bengal from 1784–1883*, Pt. III, p. 20 (1885).

had been written before the close of that century.' Dhar[1] attributes the intellectual stagnation in India after the close of the twelfth century, among other causes, to the decline of Buddhism under whose aegis science and particularly medicine had developed considerably in the universities and hospitals attached to the Buddhist monasteries, to the revival of Brahmanism and the zeal shown by neo-Brahmans in discarding and neglecting all 'those things that were cherished by the Buddhists', and finally to the unsettled state of affairs and lack of security in the country resulting from repeated foreign invasions and constant changes in government. Other factors also probably operated to bring about such a degeneration of the mental powers of the people who had been responsible for great advances in the earlier centuries, that almost up to the end of the nineteenth century no original scientific work of any importance was carried out by Indians.

(b) *Development of Scientific work in the 18th and 19th centuries*[2].

The revival of the study of sciences in India within the last two centuries was due to two main agencies, (1) Societies, and (2) the scientific officers in various Services and Survey departments of the Government of India and Provincial Governments.

(i) *Societies.*

Asiatic Society of Bengal[3]

The history of the revival of the study of Sciences in India, particularly on modern lines, began with the foundation by Sir William Jones of 'The Asiatick Society' (later known as the Asiatic Society of Bengal and now the Royal Asiatic Society of Bengal) in 1784. The objects of this Society were explained by the founder as 'If now it be asked, what are the intended objects of our enquiries within these spacious limits, we answer, Man and Nature; whatever is performed by the one, or produced by the other.' The Society fully carried out its ideals during the first century of its existence by providing :—

> 'a commodious house for scholars, the making of a library, of a collection of ancient coins and medals, of a collection of pictures and busts, and the formation of Archæological, Ethnological, Geological, and Zoological collections or Museums. In addition, the Asiatic Society had published 354 volumes of works of various kinds'.

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[1] Dhar, N. R.—*The Cultural Heritage of India*, III, pp. 452, 453 (Ramakrishna Centenary volumes; Belur, Calcutta, 1937).

[2] The following review is mainly based on the very detailed treatment of the subject in Sir Lewis Fermor's Annual Address to the Asiatic Society of Bengal for the year 1934 entitled 'The Development of Scientific Research in India to the end of the Nineteenth Century', published in the *Year Book of the Asiatic Society of Bengal*, Vol. I, 1935, pp. 9–22 (1936).

[3] The name of the Society was changed in 1936 to 'The Royal Asiatic Society of Bengal'.

The extensive bibliography of scientific papers published by the Society in the *Asiatic Researches* (Vols. I–XX, 1788–1839) and the *Journal* [1] of the Society (*vide* Centenary Review of the Asiatic Society 1783–1883, pp. i-xcvi) bears ample testimony to the great services rendered to India by this venerable institution in the cause of scientific revival.

From 1884 to 1900 was a period of great activity in the history of the Society in so far as biological investigations were concerned. The geological work, however, except for a few papers of general interest, was published in the official publications of the Geological Survey of India.

Zoology.—The Indian Museum, Calcutta, which was founded in 1866 through the efforts of the Society, had already attained its premier position as the main centre of zoological research in India, and the work initiated and carried out by its staff stands out pre-eminently in the publications of the Asiatic Society.[2] Atkinson published a large series of notes on Rhynchota ; Moore, de Niceville, Wood-Mason and H. J. Elwes on Lepidoptera ; Walsh on certain spiders that mimic ants ; and various foreign workers on different families of insects based mainly on the collections of the Indian Museum. Sclater published a paper on the Snakes in the Indian Museum collection in 1891, Frank Finn on Birds from 1897–1900, and Alcock from 1893 onwards published a series of papers on Corals, Actinians, Crustaceans and other marine animals. Frank Finn and Alcock also made interesting contributions to the Theory of Warning Colours (1896–98). In addition, two very important zoological publications printed in the *Journal*

[1] Reference may also be included here to *Gleanings in Science*, Vols. I–III (1829–31), which was afterwards absorbed in the *Journal* of the Asiatic Society, and *India Review and Journal of Foreign Science*, Vols. I–VIII (1834–1847) ; both these journals were published at Calcutta.

[2] In the above review are not included various important Zoological journals and publications which were published independently of the Asiatic Society. Among these may be mentioned 'Stray Feathers' Vols. I–XI edited by Hume (1873–1888), 'Journal of the Bombay Natural History Society' published from 1886 onwards, Marshall's 'Game Birds of India, Burma and Ceylon' (1879–81), Hewitson and Moore's 'Indian Lepidoptera' (1879–88), Marshall and de Niceville's 'Butterflies of India, Burma and Ceylon' (1882–90), Sterndale's 'Natural History of the Mammalia of India and Ceylon (1884), Oate's 'Handbook of the Birds of British Burma' (1883), Murray's 'Avifauna of the British India' (1888-90), 'Scientific Results of the Second Yarkand Mission' (1885–89), and the large number of Descriptive Catalogues of the Collections in the Indian Museum, more particularly of the marine collections obtained by the R.I.M.S. 'Investigator' published by the Trustees of the Indian Museum, Calcutta, since 1887. The most important work, however, to which reference has to be made here was the 'Fauna of British India' series which began to be published by the authority of the Secretary of State for India under the editorship of W. T. Blanford from 1888. The first part of the first volume on Mammals appeared in 1888 and up to 1900, 14 volumes on Mammals, Reptilia and Batrachia, Fishes, Moths, Hymenoptera, and Arachnida were published.

of the Society deserve special mention. The first was a series of Natural History Notes on the collections made by the Royal Indian Marine Survey ship 'Investigator'. These notes dealt with the zoological and botanical collections and observations made by the Surgeon-Naturalists; though a number of these notes was published in foreign journals, a large series of them were published in the *Journal* of the Society from 1885–96. The other monumental work entitled 'Materials for a Carcinological Fauna of India' published in 6 parts from 1885–1900 by Alcock, still remains a standard work on certain classes of marine Crustacea of the Indo-Pacific region.

Botany.—On the Botanical side, mention may be made of a series of papers on the Flora of the Malay Peninsula published by King (1889–96), and a still more valuable series under the title 'Noviciæ Indica' by David Prain (1889–98). Another very valuable series of notes on the parasitic Rust Fungi of the order Uredinæ was published by Dr. Barclay of the Bengal Medical Service (1886–91). Several papers were published by Gamble, H. F. Blanford and other authors.

Anthropology.—From 1897 a special part of the *Journal* (Part III) was devoted to the publication of results of anthropological and ethnological work by Risley, Mitra, Charles, Waddell, Weise, Bodding, Peal, Gait, Grierson, Shakespear and others on the tribes of India and the customs and habits of the inhabitants of different regions. Reference may also be made here to Bruce Foote's valuable paper on 'Some Neo- and Palæolithic Finds in S. India' published in 1887.

Mathematics.—The first original scientific contributions by an Indian printed by the Society consisted of a series of three important mathematical papers by Asutosh Mukhopadhay (Sir Ashutosh Mookerjee of later years) published in 1887. He published nine more mathematical papers on Differential Equations in the *Journal* for the three succeeding years (1888–90). The worthy example of Sir Ashutosh bore fruit before long, and from 1894 onwards papers by Indians began to appear in fair numbers in the publications of the Society. A paper by Dutt on the Method of Treating the Properties of the Circle and Analogous Matters was published in 1900.

Physics and Meteorology.—A number of meteorological contributions, particularly in reference to rainfall, tornadoes, hygrometer, etc., by Blanford, Elliot, Pearson, Hill, Pedler and others were published from 1884 to 1893. The paper on the Polarization of Electric Rays by Double Refracting Crystals by Bose (later Sir Jagadis Bose) was published in 1895.

Chemistry.—Pedler and Waterhouse contributed papers on the Volatility of Some Compounds of Mercury and the Action of Light on Silver and its Haloid Compounds. Pedler and Warden published a valuable paper on the Toxic Principle of the Aroidæ

in 1890. In 1894 Ray (later Sir Prafulla Chandra Ray) read a paper on the Chemical Examination of Indian Food Stuffs, followed by other papers on Mercury Salts from 1898–1900. The chemical papers by Nag, Pedler, Bhaduri and Bhaduri (1898), and Mukerjee (1900) should also be mentioned.

Geology.—As noted earlier in this chapter, very few papers of geological interest were published by the Society. It is, however, interesting to note that as early as 1880 P. N. Bose, after obtaining a degree in Geology in London, published a paper in the 'Quarterly Journal of the Geological Society of London' in which he described some fossil Carnivora from the Siwalik Hills. He also wrote a very critical account of the progress in Natural Science for the 'Centenary Review of the Asiatic Society of Bengal' and published a number of important geological memoirs in the publications of the Geological Survey of India to which he was appointed soon after his return from England.

Medical Science.—The only medical paper of any importance in the *Journal* of the Society was published in 1900 by Rogers (later Sir Leonard Rogers) on the Relation of Water-supply, Water-logging and Distribution of Anopheles to the Prevalence of Malaria in North Calcutta. This was apparently due to the fact that medical papers were published in special medical publications such as the 'Transactions of the Medical and Physical Society', Calcutta (1825–45), 'Indian Journal of Medical Science', Calcutta, started by Grant and Pearson and continued by F. Corbyn (1834–36), 'Indian Annals of Medical Science', Calcutta, (1853–1877), 'Madras Quarterly Journal of Medical Science' (1860–68), 'Madras Monthly Journal of Medical Science' (1870–73), and 'Indian Medical Gazette' published in Calcutta (1866 onwards). The scientific work of the medical officers of the Army of India was published in a series of special memoirs entitled 'Scientific Memoirs by Medical Officers of the Army of India' published under the editorship of the Director-General of Indian Medical Service. Twelve volumes of this journal, which was started in 1885, were issued up to 1910.[1]

Other Societies

In Madras a Society called the 'Madras Literary Society and Auxiliary of the Royal Asiatic Society' of Great Britain and Ireland was started about 1833. The Society started a journal under the name 'Journal of Literature and Science', but this title was changed to 'Madras Journal of Literature and Science' from 1834; the journal, which was published irregularly, finally stopped in 1894. An Agricultural Society of India was founded in Calcutta in 1820; in 1823 its name

[1] From 1901 the name of this publication was changed to 'Scientific Memoirs by Officers of the Medical and Sanitary Departments of the Government of India' (*N.S.*), and 60 parts were published up to 1913. The 'Indian Journal of Medical Research' started by the Indian Research Fund Association in 1912 replaced these separate memoirs and 'Paludism' which was started in 1910 for publication of work dealing with Malaria.

was changed to the Agricultural and Horticultural Society of India, and later to Royal Agri-Horticultural Society of India. The original Transactions of the Society are now issued as its Journal and Proceedings. Finally, mention may be made of the Bombay Natural History Society, which was founded in 1883. From 1886 to date 39 volumes of its well-known Journal of Natural History have been issued. Scientific papers have been published in the journals of these Societies, and they have rendered useful service in the cause of Science by publishing scientific contributions from different parts of India. The special journals dealing with medical work in India have been referred to above.

(ii) *Services.*

The East India Company did not employ any scientists as such, and almost all really scientific work in India was, therefore, carried out by medical men, Royal Engineers, and civil or military officers interested in science, mainly in their spare time.

Scientific Departments, Surveys, etc.

Among the earlier pioneers of the medical profession [1] may be mentioned Gabriel Boughton, William Hamilton, John Holwell and W. Fullerton, all of whom 'made a permanent niche for themselves in the history of India by their political, medical or literary work'. From 1766 onwards, however, the medical personnel from Europe was divided 'into a military and a civil branch, men no doubt being inter-changeable as ability and circumstances dictated'. From 1763 onwards medical services for the three presidencies of Bengal, Madras and Bombay were established, and finally came the Indian Medical Service, which, though primarily a military Service, was able to release the surplus military personnel for employment 'in civil medical fabric of medical relief in hospitals, dispensaries, jails, asylums, of medical education and of education, whilst it allowed selected officers from this "scientific" corps to be utilized in organizing many other activities such as chemical examiners' work, botanical, zoological, and marine survey work, work in Opium Department and in the mint'. Medical research organization in India dates from 1869 when Drs. Lewis and Cunningham were appointed as Special Assistants to the then Sanitary Commissioner with the Government of India, and initiated researches on diseases like Cholera, Malaria, Beri-Beri, Kala-Azar, etc. It was, however, with the creation of a regular Bacteriological Department for India with proper laboratory facilities, which was

[1] The account of the medical services and medical research organization is taken from Col. Graham's chapter in 'The Indian Empire' (Calcutta, 1927), and the reviews of the other Surveys and Departments from Sir Lewis Fermor's Address referred to already.

sanctioned in 1900, but which did not start functioning till 1906, that medical research organization in India was placed on a regular footing.

The Trigonometrical Survey of the Peninsula of India, established in 1800, was extended as the Great Trigonometrical Survey of India in 1818. The Topographical and Revenue surveys were all grouped together under the Surveyor General in India in 1817, and were consolidated with the Trigonometrical Survey in 1878 as the *Survey of India*.

The *Geological Survey of India* was founded in 1851, but Geologists had been employed since 1818 for survey work.

With the foundation of the Calcutta Botanical Gardens (now known as the Royal Botanic Gardens) in 1788, it became possible to carry on botanical studies in India. The *Botanical Survey of India* was founded in 1889.

Properly organized zoological research in India dates from the appointment of Edward Blyth as the Curator of the Museum of the Asiatic Society in 1841. He was succeeded by John Anderson in 1865, who, in 1866, on the foundation of the Indian Museum, became its first Superintendent with the zoological and archæological collections under his direct charge. Zoological research was carried on vigorously under Anderson, Wood-Mason, Alcock and later under Annandale, who in 1907 started two zoological journals, the *Records* and *Memoirs of the Indian Museum* which materially advanced the cause of zoological research in the country. In 1916, the Zoological and Anthropological Section of the Indian Museum was converted into the *Zoological Survey of India*.

From the establishment of the East India Company to 1832, when the Indian Navy Department was organized, Hydrographic work was a secondary duty of the officers of the Bombay Marine. The explorations, however, not only covered the whole of the Indian Ocean but also the Red Sea, the Persian Gulf and the seas of China. The Indian Navy continued the marine surveys up to 1862 when it was abolished, and there was no marine survey till 1874 when the Indian Marine Survey Department was established. In 1871 the Council of the Asiatic Society wrote to the Government of India urging them to start marine biological investigations in connection with their marine survey work. In 1875 the Indian Coastal Survey was established and in the same year was created the post of a Surgeon-Naturalist to the Marine Survey.

The post of an Inspector General of Fisheries in India and Burma was created in 1870, and Dr. F. Day, a medical man, was appointed to it. Dr. Day from 1871–74 carried out extensive investigations on the fisheries of the rivers of India and on marine fisheries along the entire coast from Gwadur in Baluchistan to Mergui in Tenasserim, and in 1873 published two reports on the freshwater and sea fish and fisheries of India. His monumental

work 'The Fishes of India' was published between 1875–78. The Fisheries Department of the Central Government was abolished after Dr. Day's retirement.

An *Archæological Department* under the direction of Sir Alexander Cunningham, started in 1862, carried out an extensive survey of the monuments and antiquities of Northern India, and work on similar lines was carried out in the Bombay and Madras Presidencies. Detailed research programmes were initiated from 1885, but the activities of the Department were curtailed as a measure of retrenchment in 1889, and it was not till 1902 that archæological work in all its branches was again resumed.

Meteorological observations were carried on from 1796 at the Madras Observatory founded in 1792, at Calcutta in the Survey office building from 1824 and in the Alipore Observatory from 1875 and in the Colaba Observatory, Bombay, from 1841. In 1862, a committee of the Asiatic Society, which was appointed in 1857, submitted a scheme for a central authority to direct and collate the work of observers all over the country, as a result of which H. F. Blanford was appointed the Meteorological Reporter for the whole of India in 1875. The title of the head of the Meteorological Department was later changed to Director General of Observatories.

(iii) *Applied Science Institutes.*

'In Agriculture provincial Departments of Land Revenue and Agriculture, or of Agriculture alone, were formed towards the end of the century: Bombay (1885), Madras (1889), Shillong (1894), Allahabad and Nagpur (1895) and Bengal (1896), followed by the Indian Agricultural Research Institute at Pusa in 1903. For Veterinary work the Imperial Bacteriological Laboratory was opened at Poona in 1890, moved to Muktesar in 1893, and the title changed to Imperial Institute of Veterinary Research in 1925.'

The *Haffkine Institute, Bombay,* which has developed into a well-known centre of research in preventive medicine, was started in 1899, as the Plague Research Laboratory, but gradually antirabic, pharmacological and biochemical researches have been included in its activities.

The *Indian Association for the Cultivation of Science, Calcutta,* was founded in 1876 by Dr. Mahendra Lal Sircar. Up to about the end of the first decade of the present century this institution helped in the advancement of Science by public lectures and lectures in various sciences to supplement the normal college courses, but with Prof. C. V. Raman (later Sir Venkata Raman) making the Institute as his headquarters, it developed into one of the foremost centres of physical research in India.

IV. Development of Scientific Research in India in the Twentieth Century[1].

With the beginning of the twentieth century scientific work in India began to develop at a fairly rapid rate. In the earlier years scientific teaching was confined mainly to technical institutions such as medical and engineering colleges and such other institutions as had the necessary staff and equipment. But scientific studies were gradually becoming more and more popular all over the country, and of the much larger numbers of Indian students, who had by this time started going to Europe for under-graduate and post-graduate studies, a fair number took up the study of Science in one or other of its branches. Scientific research by various scientific Services and Departments of the Government was also developing at a rapid rate, and the scientists working in different parts of the vast subcontinent of India gradually began to feel ' the *geographical isolation* ' in the case of those who lived in places where there were few or no other scientists, and ' *specialist isolation* of large numbers of scientists one from another due to their specialization '. This resulted in the formation of various scientific societies and co-ordinating organizations, all of which have materially helped to bring Indian Science to its present position.

Universities

Reference has already been made to the universities founded in the nineteenth century, but none of them, as noted above, was a teaching institution. It was only as a result of the provisions in the University Act of 1904, that a number of them began to undertake direct teaching functions, particularly in reference to post-graduate work and research. Scientific education also received a special impetus from about 1906 onwards when chairs for various sciences were created in Government colleges and some private institutions throughout the country.

The *Calcutta University*, which played a very important rôle in the promotion of Science, and encouragement of research, deserves special mention. In 1909, provision was made for Post-Graduate teaching, and in 1917 all Post-Graduate studies were centralized in Calcutta. This was rendered possible through the munificence of two great men of Bengal, Sir Tarak Nath Palit and Sir Rash Behari Ghosh, who created large trust funds to be administered by the Calcutta University for the promotion and diffusion of scientific and technical education and the cultivation and advancement of pure and applied sciences. With these endowments the University College of Science, Calcutta, started in

[1] In the preparation of this section I have drawn freely on Sir Lewis Fermor's Inaugural Address to the National Institute of Sciences of India—*Proc. Nat. Inst. Sci. India,* I, pp. 10–26 (1935).

June 1916 Post-Graduate classes in Physics, Chemistry, Applied Mathematics and Experimental Psychology; Applied Chemistry and Applied Physics were added in 1919. An endowment from Kumar Guruprasad Singh of Khaira enabled the University to add two more Chairs to its Post-Graduate teaching staff, while a few special Chairs were also founded out of the reserve funds of the University. For this far-sighted policy the Calcutta University is indebted to the genius of the great educationalist of India, Sir Ashutosh Mookerjee, who, undaunted by opposition, worked hard to raise the Calcutta University to the proud position it occupies to-day, not only as one of the leading universities in India but also as one which has done more than any other institution in the country for the promotion and advancement of Science.

Few of the other Indian universities have been so fortunate as to obtain such princely endowments from the public for teaching and research as Calcutta, but the records of their service in the cause of Science are none the less praiseworthy. Several of the universities, founded since the Report of the Calcutta University Commission was published in 1919, are of the unitary type; they are usually localized in a single centre and their teaching is conducted by teachers appointed and controlled by them. Even the affiliating universities have gradually taken up teaching functions; almost all of them maintain Chairs of Chemistry and Physics and several of them have Chairs of Botany and Zoology as well. Geology, however, is taught in three or four universities only. Some universities, such as Calcutta, Benares, Bombay, etc., also have some Chairs in Applied Sciences.

Most of the universities of India have flourishing schools of research in various sciences and during the past decade a great deal of original work of very high quality has emanated from them; they are gradually beginning to fulfil their proper functions not only as centres of teaching but also of encouraging and promoting original work by their staffs and students.

Research Institutes

During the period under review the Government of India has established a number of very important research institutes. The *Imperial Agricultural Research Institute* was founded at Pusa in 1903 as a result of a generous donation towards part of its cost by an American philanthropist, Mr. Henry Phipps. A separate Sugarcane Breeding and Research Station of the Institute has been working at Coimbatore since 1912. The Pusa Institute was severely damaged by the Bihar earthquake of 1934, and transferred to New Delhi in 1936. The *Central Research Institute for Medical Research* at Kasauli with its Malaria section, which later developed into the Malaria Survey of India, and the *Forest Research Institute* at Dehra Dun were started in 1906. The *Imperial Dairy Institute*, Bangalore, was established in 1920 to carry out researches in Dairy Husbandry, and develop the dairy industry on proper lines. The *All-India*

Institute of Public Health and Hygiene, Calcutta, which started work in 1934, owes its existence to the Rockefeller Foundation, which paid for the cost of the site, the building and the equipment of the Institute ; the recurring cost of the staff and maintenance is borne by the Central Government. In addition there are several well known research institutions which are maintained and administered by the Provinces. Of Medical institutes in this category the Haffkine Institute, Bombay, has been referred to already, others in chronological order of their foundation are : the King Institute of Preventive Medicine, Guindy, Madras (1903) ; Pasteur Institute of Southern India, Coonoor (1907) ; King Edward VII Pasteur Institute and Medical Research Institute, Shillong (1917) ; and finally the Calcutta School of Tropical Medicine (1921), which has already established an international reputation in the field of medical research. Of the provincial *Agricultural* institutions the following, in addition to teaching, carry out original investigations : the Agricultural College and Research Institute, Coimbatore ; the Agricultural College and Research Institute, Lyallpur ; and the Cawnpore Agricultural College. The *Irrigation Research Laboratories* of the Governments of the Punjab, Sind and the United Provinces may also be referred to here. The Poona Research Laboratory financed by the Government of India is to be the nucleus for a Central Station for Irrigation and Hydrodynamic Research of the Central Board of Irrigation constituted in 1925. Departmental research sections on similar lines are maintained by the Railway Board, Telegraphs, All-India Radio and other technical Departments of the Central and Provincial Governments.

In this section are also to be included the *Indian Institute of Science*, Bangalore, which owes its origin to the genius and munificence of Sir J. N. Tata. It was founded in 1911 for advanced scientific education and research, supported mainly by the private bequests of the Tata family, supplemented by the grants by the Government of India and Mysore State ; the *Bose Research Institute*, Calcutta, founded and endowed by the late Sir Jagadis Bose in 1917 for post-graduate research ; the *Cotton Technological Loboratory*, Bombay, the *Institute of Plant Industry* at Indore, established in 1924 ; the *Indian Statistical Institute*, Calcutta, started in 1931 for the study of pure and applied statistics and for the encouragement of research and dissemination of knowledge of these subjects ; and the *Indian Lac Research Institute*, Ranchi, started in 1925. The *Nutritional Research Institute*, Coonoor, maintained by the Indian Research Fund Association, has also been working for a number of years.

Specialist Societies

Sir Lewis Fermor in discussing the development of scientific research in India remarked that in the 20th ‘century we have entered on a new stage in the development of scientific research in India,

a period characterized by the formation of numerous specialist scientific societies and numerous Government research institutes.' The first society was the Mining and Geological Institute of India, founded in 1906. The Indian Mathematical Society was started in 1907 at Poona as the 'Analytical Club' but the name was soon changed to the Indian Mathematical Club; its office at present is at Nagpur, but the Society's journal is published from Madras. The Calcutta Mathematical Society was founded in 1908; the Institution of Engineers (India) was constituted in 1920, with its headquarters in Calcutta and branches in several other important towns; the Indian Botanical Society, with peripatetic headquarters, in 1921; the Indian Psycho-Analytical Society with headquarters at Calcutta in 1922; the Indian Chemical Society with its headquarters in Calcutta, and the Geological, Mining and Metallurgical Society of India, in 1924; the Indian Psychological Association in 1925; the Society of Biological Chemists, Bangalore, in 1931; the Indian Physical Society, Calcutta, and the Biochemical Society in 1934; the Indian Society of Social Science and the Indian Physiological Society in 1935; and the Indian Anthropological Institute, Calcutta, in 1936. Among the societies with more restricted geographical scope may be mentioned the Bihar and Orissa Research Society, Patna (1915); Benares Mathematical Society, Benares (1918); the Anthropological Society, Calcutta (1920); the Calcutta Geographical Society (1933) and the Botanical Society of Calcutta (1935).

Co-ordinating organizations

In 1935, Fermor[1] in discussing the development of Science urged the great necessity of co-ordinating organizations for scientific work in India as follows:—

> 'With this multitude of new bodies—services, societies, universities, research institutes—coming continuously into being, with a resultant tendency towards greater and greater specialization and consequent isolation of workers, there is an increasing need for organizations directed to counteracting fissiparous tendencies so as again to bring men of science and other branches of learning back to a common fold providing for a free exchange of views: a result that can be secured either on a comprehensive basis enabling the co-operation of all branches of learning, or at least of all branches of science, or upon a compartmental plan in which allied groups of sciences are brought together'.
>
> 'At the beginning of this century the only organization directed to this end in a really comprehensive manner was the Asiatic Society of Bengal'.

The Government of India, in 1902, established the *Board of Scientific Advice* for the co-ordination of scientific work carried out by official agencies. This Board met periodically to discuss problems of common interest and published an Annual Report, summarized subject by subject, on the progress of research in

[1] *Proc. Nat. Inst. Sci. India*, I, p. 13 (1935).

India by the Scientific Departments and institutions of the Government. The reports of the Board were communicated through the Secretary of State for India to the Royal Society of London, which with the help of an Advisory Committee used to advise the Board and the Government with valuable suggestions from time to time. The activities of this Board were suspended in 1924. Proposals for a National Research Council to replace this Board were under consideration for several years, but the scheme has not hitherto materialized.

The *Indian Research Fund Association* was founded in 1911, by the Government of India for the prosecution and assistance of research in connection with the causation, mode of spread and prevention of diseases. For the past two decades the Association has served not only as an important co-ordinating agency for research in medical and public health problems by all Government agencies, but also employs a fairly large staff for special enquiries and gives grants-in-aid to various institutions and research workers. In connection with its programme of work the Association is guided by an annual Medical Research Workers' Conference which used to be held every December in Calcutta; since 1937 onwards, however, its venue has been transferred to New Delhi.

The *Imperial Council of Agricultural Research* was constituted in 1929, with substantial annual grants from the Government of India as a result of the recommendations of the Royal Commission on Agriculture. Out of these grants the Council allocates funds for Agricultural and Veterinary enquiries throughout the country and holds periodical meetings for considering the reports and allocating the available funds. There are also two auxiliary Committees of the Imperial Council, viz., the *Indian Central Cotton Committee* constituted in 1921, and financed by a cess of two annas a bale on all cotton produced in India; and the *Indian Central Jute Committee* constituted in 1937, and financed from the Central Revenues. These Committees have been constituted for arranging agricultural, technological and economic research in connection with the improvement of cotton and jute crops in the country and the factors connected with the marketing of the products. They are also concerned with the production and distribution of improved qualities of seed.

Privately endowed Associations of a similar nature are the *Indian Lac Cess Committee*, the *Indian Coffee Cess Committee*, and the *Indian Tea Association* at Tocklai in Assam. These three Committees have helped materially, by research and propaganda, in improving the standards of lac, coffee and tea.

All-India Academies

Up to almost 1930 the only literary and scientific society of an all-India status was the *Asiatic Society of Bengal*, Calcutta. Ever since its foundation this Society, as has been described above, has done yeomen service in the advancement of both Arts and Sciences.

In 1930, the *United Provinces Academy of Sciences* was founded at Allahabad to provide for the meeting of students of all branches of sciences in Northern India. It was renamed the National Academy of Sciences, India in 1936.

The *Indian Academy of Sciences*, Bangalore, was started in 1934, with a view to holding regular meetings for reading and discussion of original scientific contributions and for arranging symposia on subjects of special interest. In addition the Academy provides in its *Proceedings* a valuable agency for the publication of papers without delay; these are issued every month in two parts, (i) Physical and Mathematical Series, and (ii) Biological Series.

The *National Institute of Sciences of India*, with its headquarters at Calcutta, owes its existence [1] to the need keenly felt by scientific men all over the country for a body which could co-ordinate the work of various scientific societies, institutions, and Government Scientific Departments and Services throughout the country. With this end in view a special Committee was appointed at the Bombay Meeting of the Indian Science Congress Association in 1934. This Committee submitted detailed proposals for consideration by the Calcutta Session of the Indian Science Congress in 1935 and as a result the National Institute of Sciences was inaugurated in Calcutta on 7th January, 1935. Its programme of work was outlined as :—

> '(*a*) The promotion of natural knowledge in India including its practical application to problems of national welfare.
>
> (*b*) To effect co-ordination between scientific academies, societies, institutions, and Government scientific departments and services.
>
> (*c*) To act as a body of scientists of eminence for the promotion and safeguarding of the interests of scientists in India: and to represent internationally the scientific work of India.
>
> (*d*) To act through properly constituted National Committees in which other learned academies and societies will be associated, as the National Research Council of India, for undertaking such scientific work of national and international importance as the Council may be called upon to perform by the public and by Government.
>
> (*e*) To publish such proceedings, journals, memoirs and transactions, and other publications as may be found desirable.
>
> (*f*) To promote and maintain a liaison between Science and Letters.
>
> (*g*) To secure and manage funds and endowments for the promotion of Science.
>
> (*h*) To do and perform all other acts, matters, and things that may assist in, conduce to, or be necessary for the fulfilment of the abovementioned aims and objects of the Institute.'

[1] For further details in connection with the history and foundation of the National Institute reference may be made to *Proc. Nat. Inst. Sci. India*, I, pp. 30–46 (1935).

Indian Science Congress Association[1]

The isolation of scientific workers in India and the almost entire absence of scientific societies in India led Prof. J. L. Simonsen of Madras and Prof. P. S. MacMahon of Lucknow, in 1911, to propose the formation of an Association analogous to the British Association for the Advancement of Science. The replies received to the appeal of the sponsors made it clear that there was a general consensus of opinion in favour of starting an association of this type, and in 1912, therefore, a Committee of 17 foremost men of Science in India was selected to arrange for the holding of the first meeting. The Asiatic Society of Bengal was asked to undertake the management of the proposed Indian Science Congress,[2] and the first meeting was held in the rooms of the Asiatic Society of Bengal at Calcutta on January 15–17, 1914, with Sir Ashutosh Mukhopadhyaya as its first President. The first session of the Congress consisted of six sections, Chemistry, Physics, Geology, Zoology, Botany and Ethnography, and about 35 original papers were read. The annual sessions of the Congress last for one week and following the plan of its model, the British Association for the Advancement of Science, the venue of its meetings is changed from one city to another. The second to seventh meetings of the first circuit were held from 1915–20 at Madras, Lucknow, Bangalore, Lahore, Bombay and Nagpur. The eighth to fourteenth sessions of the second circuit were held from 1921–27 at Calcutta, Madras, Lucknow, Bangalore, Benares, Bombay and Lahore, and the third circuit sessions from 1928–34 were held at Calcutta, Madras, Allahabad, Nagpur, Bangalore, Patna, and Bombay. The first three sessions of the fourth circuit were held at Calcutta, Indore and Hyderabad from 1935–37, and the Silver Jubilee Session, the fourth session of the fourth circuit, was held at Calcutta in 1938 from January 3–9. At the Jubilee Session of the Congress there were 13 sections (Mathematics and Physics, Chemistry, Geology, Geography and Geodesy, Botany, Zoology, Entomology, Anthropology, Agriculture, Medical Research, Veterinary Research, Physiology and Psychology) as compared to 6 in 1914, while the number of papers communicated to the different sessions increased from about 35 in 1914 to over 800 in 1938; in addition there were 22 discussions in individual sections and 10 joint discussions of various sections. This meeting was a joint session with the British Association for the Advancement of Science. A very representative delegation of members of the

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[1] A special volume by Prof. S. P. Agharkar on the history of the Indian Science Congress Association will be issued at a later date.

[2] The name Indian Science Congress was adopted in view of there being already in existence in Calcutta an Indian Association for the Cultivation of Science with objects entirely different from those of the proposed Association. In 1935 the name of the Congress was changed to Indian Science Congress Association.

British Association and also scientific workers from other parts of the world attended this session. The great success of the Science Congress is proved, if any proof is needed, by the large number of scientists from all parts of India who now attend its sessions and the size of the annual volume of its *Proceedings*. The organization has proved of very great value in promoting intercourse between the scientists of all parts of India, and there can be no doubt of its services in the cause of the advancement of Science.

In the following pages I give short summaries [1] of the advances in various sciences in India [2] as detailed in Chapters II–XVIII of the volume.

Scientific Education

Dr. Jenkins (pp. 1–17) considers the arrangements for scientific education in India to be far from satisfactory. Scientific education, if imparted on proper lines, must be 'a natural cultural educational and give 'the foundation on which a satisfactory practical scheme of life can be built.' The first issue is considered by the author to be the 'more fundamentally important aspect of scientific training' for which a good foundation can only be laid in the schools. After discussing the unsatisfactory nature of scientific education in the schools in the different provinces, Dr. Jenkins puts forward a very strong plea for the provision of necessary facilities for the teaching of science, including training of science teachers and the provision of laboratory equipment in the Middle and High schools. The question of the curricula for scientific teaching is discussed, and stress is laid on the fact that without a 'satisfactory foundation training in the scientific principles and in the elementary branches it will be impossible for the universities to achieve reasonably good results and provide teaching that is really of the university standard'. In this connection reference is also made to the lowering of the 'age limit' for admission to the universities. In regard to higher education, Dr. Jenkins comments on the remarkable quantitative expansion of scientific education in colleges, and considers the facilities available for the teaching of the large number of students with an inadequate pre-university preparation far from sufficient. He favours the Three Years Honours course and suggests that the course for the Pass Degrees also should extend to 3 years. The different standards for similar examinations in various universities are commented on, and attention is directed to the lack of correlation of subjects for various Degree examinations in certain universities. Post-graduate studies

[1] The above summaries are based on the accounts of the various contributors and do not necessarily represent the views of the Editor.

[2] The Section entitled 'The Pursuit of Science' in Vol. III of *The Cultural Heritage of India* (Ramakrishna Centenary Volumes, Belur, Calcutta, 1937). deals among other subjects with Mathematics in Modern India; Botany in India—Past and Present; India's contribution to Chemical Knowledge; and India's contribution to Modern Physics.

have developed in most Indian universities at a very rapid rate on the lines of the scheme devised by the late Sir Ashutosh Mookerjee for the Calcutta University, and as a result, according to the author, 'the volume of research work which is now being done is remarkable considering the unsatisfactory nature of school and college education and the financial resources of the different educational institutions.' Dr. Jenkins concludes by stating that 'much has been done, but that much remains to be done' and progress, rapid as it has been, will be still more rapid and effective with (1) the reorganization of secondary school systems so as to guarantee a sound fundamental education and preliminary scientific training, (2) the reorganization of university studies so as to guarantee a sound knowledge of all the fundamental sciences to serve as a foundation for advanced scientific study and research in any branch, (3) the co-operation of industrial and commercial firms in connection with research activities in various directions, and (4) securing endowments for research in the pure sciences which have no immediate direct commercial applications.

Mathematics

In reviewing Mathematical Research in India (pp. 18–43), Principal Sen refers to the pioneer works of Sir Ashutosh Mookerjee on Differential Equations carried out during the eighties of the last century and of Dr. Ganesh Prasad in various branches from 1900–1935. The outstanding figure in the field of Indian mathematics in modern times was Srinivasa Ramanujan, whose rise to fame provides a romantic touch to the matter-of-fact atmosphere of scientific research. Born of poor parents, his educational career came to an early end, and he had to start life as a clerk in the Madras Port Trust. The discovery of his natural genius for mathematical work, his subsequent work at Cambridge under the guidance of his admirer and mentor, Prof. G. S. Hardy, his election as a Fellow of the Royal Society of London at the early age of 31 and the tragic end of his life so full of promise only two years later cannot be dilated on here. Most of his important work relates to the Theory of Numbers; his analysis of highly Composite Numbers is most remarkable and shows an extraordinary mastery over the Algebra of inequality. In the Theory of Partition his genius appears in all its brilliance and the Rogers-Ramanujan formulæ are works of surprising elegance and beauty. His treatment of Elliptic and Modular Functions is equally masterly, and there can be no doubt that he opened up new lines of research in all the branches he took up.

In *Geometry* a great deal of work has been carried out on the differential geometry of curves, the properties of convex ovals and ovaloids in relation to various types of centroids and concurrency theorems of hyperbolic triangles. The geometry of quadric manifolds and geometrical transformations, the tetrahedra, and the conicoids have been the subjects of detailed investigations, while

the classification of double surfaces under certain rest
the theory of deformations have received some attent
problems in plane, algebraic and differential geometry have also been investigated.

Algebra and algebraic equations have attracted a large number of workers, and a large number of papers have been published on the Theory of Functions and Infinite Series.

The work of Ramanujan on the *Theory of Numbers* referred to above, has been extended by a number of Indian workers, and Arithmetical Functions have also received some attention.

During the period under review a fair amount of work in Hydrodynamics, Theory of Elasticity, Theory of Relativity and Theory of Light has also been published.

Researches in theoretical *Statistics* in India were started by Sir Gilbert Walker about a quarter of a century ago, and during the period under review, a fair amount of work of great practical importance in connection with weather forecasting has been carried out. The work in statistics has received a great impetus since the foundation of the Statistical Institute at Calcutta.

Finally, mention may be made of the mathematical work in connection with Seismology, Meteorology, Terrestrial Magnetism, etc., histories of Mathematics in ancient India and the papers on Hindu Astronomy published by a number of workers.

Chemistry

In his review of Chemical Research in India during the past twenty-five years (pp. 44–85) Prof. Ghosh points out that at the beginning of the period under review there were only a few centres for chemical research in the country and the number of workers was also limited. With the foundation of the University College of Science, Calcutta, and of a number of universities at the beginning of this period, however, the facilities for scientific research were materially increased. The impetus given by the World War and the development of Indian industries resulted in a greater demand for trained chemists, and fortunately the importance of a training in research in the equipment of such chemists was considered essential. The foundation of the Imperial Council of Agricultural Research and the technological laboratories working in association with it, as also of the School of Tropical Medicine and the All-India Institute of Hygiene, Calcutta, the Institute of Nutrition, Coonoor, the Indian Institute of Science, Bangalore, and the well equipped chemical laboratories of the Punjab University has helped materially to broaden the field covered by chemical research in India.

At the beginning of the period work in *Physical Chemistry* made rapid progress. Researches in electrochemistry, colloids, mechanism of induced reactions first attracted attention, and work on the kinetics of chemical reactions both in the dark and in light gradually increased, both in volume and scope. The study of colloids spread with great rapidity, and for a time seemed to over-

shadow the interests in other branches of the subject. Important investigations have been carried out on the kinetics of coagulation, electrochemistry of colloids and the study of emulsions.

During the past few years a large body of workers has been studying the magnetic properties of *chemical compounds*, a subject of great interest both to the physicist and the chemist, and important contributions have already been made in this field. The physical properties of rare gases of the atmosphere and of gases and vapours, including the Raman Spectra, have also been actively investigated.

The progress of research in *Inorganic Chemistry*, though not so marked, has led to important results. Studies on co-ordination compounds and co-ordination valency, development of macro- and micro-analytical methods, compounds of boron, and a number of other interesting chemical reactions have been carried out in fair detail.

Terpenes and terpene derivatives, synthetic dye-stuffs and the relation between their colour and molecular constitution, have formed some of the main lines along which research in *Organic Chemistry* has progressed. In addition, researches on the synthesis and chemical constitution of heterocyclic compounds, specially those containing oxygen, nitrogen and sulphur, have been actively pursued, and within recent years the preparation of valuable pharmacological synthetic products has attracted considerable attention. The interest in natural products has been extended to plant and animal products, including oils and fats, alkaloids, etc., while the isolation, and the study of pharmacological properties of the active principles of indigenous medicinal plants is leading to valuable results.

In the field of *Industrial Chemistry* progress is not so marked, but the establishment of departments of applied chemistry in several universities and of official and non-official technological industries during recent years shows that Industrial Chemistry is receiving its due share of attention. Of the subjects which have already attracted attention, mention may be made of researches on oils and fats, soaps, essential oils, wood and cellulosic substances, jute, sugar, tannin, lac and shellac, coal and coke, and gaseous fuel.

The importance of *Biochemistry* in relation to problems of human nutrition, Animal Husbandry and Agriculture has given a great impetus to its study in India within recent years. Nutrition problems of man, animals and plants, deficiency diseases, enzyme actions, serological studies of normal and pathological subjects, soil microbiology, fermentation, vitamins, venoms, oxidation processes in biochemical systems, illustrate the wide range of problems that have been taken up and investigated.

Geology and Geography

A detailed account of the progress of Geology and Geography in India during the past twenty-five years has been contributed by Mr. Wadia (pp. 86–132).

The *Archæan rocks*, which constitute the main body of the Peninsular shield and are the carriers of the principal ore-deposits of the country, present many difficult problems of stratigraphic sequence and correlation, but concentrated work by the Geological Survey of India and the Mysore Geological Department during the past 25 years has thrown a great deal of light on these problems. The principal divisions of the Archæans of the Peninsula, based on recent work, are indicated in a tabular form. Detailed survey of the great pre-Palæozoic rock-systems of Rajputana has cleared up their geotectonic relations, and the part played by its northern promontory, the 'Punjab wedge' in moulding the orientation of the Himalayan, and possibly also of the Karakoram and Ferghana ranges. The Archæans of the Central Provinces, Chota Nagpur and Mysore State, and the Himalayan Archæans have also been studied in fair detail.

The geological investigations of the last two decades have not materially altered the basic ideas regarding the *Gondwana System*, but there has been a marked advance in classificatory details, the study of the floras and faunas of the period and in precise fixation of the age of the basal boulder-bed as Uralian. In view of the fact that 98 per cent of the Indian coal is derived from the Lower Gondwanas, and the total reserves of good grades are estimated at less than 5,000 million tons, recent work attaches great importance to the question of the conservation of this important mineral fuel.

The age of the *Deccan Trap* is a matter of great scientific interest. As a result of recent palæobotanical and palæozoological work it appears to be of Eocene age rather than of late Cretaceous age as it was hitherto believed to be 'on stratigraphical evidence and field relations of the traps to the formations below and above them.'

The detailed stratigraphic study of the *Salt Range* has definitely proved the existence of several thrusts of immense dimensions (*nappes*), and brought the much vexed question of the age of the great rock-salt deposits of this area nearer solution.

The *Tertiaries* of Northern India and Burma have, during the period under review, received a great deal of attention, partly owing to their rich fossil faunas, and partly because of the association of oil and coal with the Tertiary strata.

As a result of recent work very important advances have been made in our knowledge of the structure of the *Himalayas*. Tectonic work in Kashmir, Simla and Garhwal Himalayas has materially changed the old ideas. Enormous tangential thrusts have been proved in these areas, whereby slices of the mountains have moved forward for miles, piled upon each other and folded back. The last of these great earth-movements, in the Punjab at least, has now been proved to be geologically as recent as Middle Pleistocene.

The *Indo-Gangetic Trough* has since the Bihar earthquake of January 1934 received considerable attention. The northern rim of the great Trough, which is under considerable tectonic strain, forms the belt encompassing the epicentres of the majority of the known earthquakes of Northern India.

Palæontological work during the period has been concentrated mainly on the invertebrate faunas of the older Palæozoic and Anthracolithic formations of the Himalayas, Burma and the Salt Range; Tertiary Mammalia; Cretaceous Dinosaurs; Jurassic Cephalopods and the Gondwana Floras.

During the past 25 years there has been a remarkable progress in the field of *Economic Geology* in India. The Geological Survey of India is now devoting more attention to (*a*) the industrial and economic aspects, and (*b*) engineering, soil, water-supply and kindred problems.

The section on *Geography and Geodesy* includes a brief summary of 'the geographical work done in India during the last century and half' in connection with the topographical mapping of India. Reference is also made to the survey and exploration of the Himalayas, and the air-survey of about 12,000 square miles by aerial photography since 1923. The revival of geodetic activity in India has proved the inadequacy of the Isostasy Hypothesis for explaining Gravity anomalies by isostatic compensation. The Gravimetric survey has now definitely proved a deep-seated belt of excess of density underneath the plains, running N.W. and S.E. from Karachi to Orissa, with belts of defects of density to its north and south. Geodetic measurements in India repeated at intervals do not lend any support to crustal movements postulated by some authorities, nor has the work on astronomical latitudes provided any evidence of continental drift as enunciated by Wegener.

Agricultural Science

In the review of the progress of Agricultural Science in India during the past twenty-five years by Dr. Burns (pp. 133–186) the development of Agriculture on scientific lines in the country is traced to the recommendations in the *Report of the Famine Commission* (1880), Dr. Voelcker's Report on the *Improvement of Indian Agriculture* (1883) and the Report of the *Royal Commission on Agriculture* (1928). 'The central and provincial Agricultural Departments of India in their present form came into being' as a result of the recommendations of the first two reports, while the Imperial Council of Agricultural Research, which 'is now the great organizing and co-ordinating influence in agricultural research throughout India', was established in 1929 in accordance with the recommendations of the Royal Commission.

Plant Breeding attracted the attention of various workers in India at an early date. In the first period rapid success was achieved as a result of the great wealth of unselected material available for plant breeding, but owing to insufficient knowledge

of genetics the yield of new breeds was not very encouraging. This was followed by 'a second period of rapid progress due to the greater applicability of modern genetical knowledge and bolder conceptions of what could be obtained by bringing in new genes from distantly related and often wild species'. As a result improved strains of various crops have become available and the progress in the field as a whole has been remarkable. In *cotton* several improved, commercial varieties such as 289F in the Punjab, Jaywant in Bombay, and Verum selections in the Central Provinces deserve special mention. A great deal of work has been done on *wheat*, and several strains of high quality, such as Howard's Pusa wheats, Punjab 8A and some of the Bombay Khapli crosses such as 808, have been produced. Intensive research has also been directed to the selection of species resistant to Wheat Rust. The number of varieties of *rice* cultivated in India is very large, and of these, by selection and hybridization, several better strains have been produced—the ones deserving special mention being the Kolamba 42 in Bombay and a strain immune to Rice Fly attack selected in the United Provinces. The greatest triumphs of the plant-breeders in India, however, have been achieved in connection with *sugarcane*, which has provided spectacular results in the way of hybrid and crossed varieties suitable for every situation in India where sugarcane can be grown. Most of the new, so-called 'Co' (=Coimbatore) varieties yield much higher quantities of sugar than the parent species. *Millets*, *oil-seeds* and various miscellaneous crops such as chilly, hemp, potatoes, etc., have also received attention.

Extensive studies have been carried out on *plant diseases* due to fungi, and striking results have been obtained in the control of Red Rot of sugarcane, Bud Rot of cocoanut, Kolerog disease of the areca palm and the wilt disease of cotton, etc.

Insect pests of crop plants have received considerable attention, and a great deal of high class work in connection with the elucidation of the life-histories and control measures for these pests has been carried out during the period under review. Special mention may be made of the extensive *locust survey* during the last seven years beginning in December 1930 under the aegis of the Imperial Council of Agricultural Research. The data collected will, it is hoped, make it possible to deal effectively with the locust problem. Reference may also be made to the successful control of Pink and Spotted Bollworms of cotton. Sugarcane pests and pests of the fruit trees have also received a considerable amount of attention.

A great deal of research has been devoted to the *reclamation of alkali soils*, *soil acidity* and *hydrogen-ion concentration*, *base-exchange* and *soil colloid*, *soil fertility*, *soil microbiology* and finally *soil surveys*. The most striking advances in this section are the application of the new ideas of the Russian soil scientists to soil classification in India, and the working out of standard methods

for the conservation of moisture by the dry farming research stations. Studies on the *Chemistry of plant and plant products*, have also yielded valuable results.

Although a great deal of attention has been paid to tractors and other mechanical agencies for ploughing, etc., definite improvements have been carried out in the indigenous implements. As an example of the achievement of agricultural engineering research, the success of land development in the way of contour bunding which has been developed in certain provinces, notably Bombay, may be mentioned.

Plant Physiology and *Biochemistry* have received a fair amount of attention at the hands of a number of workers, and our knowledge as regards the water requirements of plants has, as a result, considerably increased.

The application of *statistics*, particularly Fisher's methods to agricultural experiments has opened new lines for detailed work.

A great deal of research has been directed towards the production of grass and other crops for *fodder*. Great advances have been made in this direction, but the pressing need at present is judicious crop planning whereby a larger area can be set aside for intensive fodder cultivation.

Notable advances in *fruit culture* are indicated by the India-wide awakening of interest in fruit culture, by the development of research stations and appointments of fruit specialists in almost all provinces. A great deal of work has been carried out on the classification, propagation methods and important diseases of various fruits. With this work may also be associated the advances in the canning of fruits and the bottling of fruit juices, as also the work in connection with the cold storage and transport of fruits.

The application of the modern methods of enquiry to agricultural economics has yielded valuable data regarding individual and village economics.

Veterinary Research

In reviewing the progress of Veterinary Research in India from 1911–1936 (pp. 187–235) Mr. Ware does not confine himself to the restricted spheres of animal pathology or animal medicine, but includes researches in allied sciences which form the background of comprehensive work on Animal Husbandry. The major part of the research work during the period has been carried out at the Imperial Veterinary Research Institute, Muktesar, but within recent years the Imperial Council of Agricultural Research has provided 'the funds for the appointment of a Veterinary Disease Research Officer in each British Province and Hyderabad State'.

Systematic investigations of the diseases of domestic animals during the period by the Imperial Veterinary Research Institute in collaboration with the Civil Veterinary Department and veterinary colleges of various provinces have resulted in the collection

of precise information on many problems connected with the disease and ill health of livestock in India.

During the early part of the period efforts were concentrated on the control and eradication of rinderpest. The preparation of a vaccine for the control of this dreadful disease of cattle by means of a goat-virus, which has been fixed at a low level of virulence for the ox-tribe, has proved highly successful for controlling, at a very low cost, serious outbreaks of rinderpest amongst cattle. A great deal of research has also been carried out in connection with the prevention and treatment of other bacterial diseases such as Hæmorrhagic septicæmia, Anthrax, Black-quarter, Tuberculosis, Johne's Disease, Glanders, Strangles, Poultry and Canine Diseases, etc. The various means devised to combat these diseases have consisted of (i) protective substances such as sera, vaccines and viruses for the treatment, and (ii) diagnostic and serological tests which help in determining the incidence of some of the diseases.

A great majority of *protozoan diseases* of domestic animals, such as Surra ; Dourine, Bovine, Canine and Equine Piroplasmoses ; Theileriasis ; Anaplasmosis ; Leishmaniasis, etc., have been investigated. Special mention may be made of the control measures for Surra evolved as a result of careful research, and which have enabled the disease to be brought under satisfactory control.

The period has witnessed a growing recognition of the importance of detailed studies of diseases for which *dipterous insects* and *arachnids* act as vectors. As a preliminary essential to the formation of working hypotheses with regard to the species which act as vectors for the transmission of such diseases in the country, a considerable amount of work has been carried out on the systematics of the Diptera and Arachnids. In connection with the transmission of Surra various species of Tabanidæ have been investigated, with negative results. The investigations on the vectors of rinderpest also have not so far led to any definite conclusions. Experimental work has been carried out on various ticks and mosquitoes in connection with tick fever of dogs and other diseases.

Considerable advances have been made in the elucidation of a number of important disease conditions due to *helminthic parasites*, in particular to Schistosomes and larval forms of Filariæ, and in the case of Schistosome diseases it has been possible to devise highly successful methods of treatment.

'It is now recognized that the breeding of domesticated animals is a science, knowledge of which can act as a safe guide to all breeders who follow certain laws of selection and mating on the one hand and scientific feeding on the other.' With this basic idea cross-breeding, selective breeding, etc., have been resorted to with a view to producing better milk-yielding and draught breeds. This quest for dual-purpose animals, which should combine milk and draught as the two essential qualities of the breeds, has unfortunately held back improvement in both classes of breeds,

as the desired combination of qualities seems impossible. Purity of stock and pedigree questions have also received considerable attention and problems of animal genetics are being studied in connection with special herds. Buffalo, goat, sheep, horse and poultry breeding are also receiving a fair amount of attention.

Systematic investigations have brought to light a number of disease conditions, the causes of which were hitherto obscure but which have now been shown to be due to *nutritional deficiencies*. Problems connected with coarse fodders, hays, rice straw, fodder conservation, etc., have been the subject of considerable research, and in view of the great importance of the fundamental problems connected with the nutrition of animals a Central Institute for Animal Nutrition Research is to be started at Izatnagar, while subsidiary research stations will be located at Coimbatore, Lyallpur and Dacca for the study of the more local problems.

Dairy Husbandry

Dairy Husbandry in India, as Mr. Kothavalla points out in his review (pp. 236–254), was not organized on a scientific basis till after the World War. In earlier years a great deal of very valuable pioneer work in the development of the dairy industry in India was carried out by the Military Dairy Farms Department of the Government of India by the establishment of dairy farms in almost all the important military stations in the country. The experience gained by the successful running of these large concerns on sound, scientific lines proved not only invaluable for future work, but also laid the foundations of modern dairy farming in India.

The Imperial Dairy Expert was appointed in 1920, as a result of the recommendations made by the Board of Agriculture in 1916, while the institutions dealing with animal husbandry were separated as a distinct organization from the Imperial Institute of Agricultural Research a few years later. The programme of work of the new organization, which proposed to deal not only with milk and milk products, but also with the breeding, feeding and management of dairy animals was outlined as :—(1) Dairy education, (2) research on various problems connected with dairy husbandry in India, and (3) to act as an advisory agency for the guidance of trade in the preparation and disposal of dairy produce. Concentrated work has been carried out along these lines ever since by the Central Agency, while the provincial organizations have helped 'mainly by the improvement of the cattle breeds indigenous to the various provinces'.

In regard to *Dairy Education*, the Government of India instituted the Indian Dairy Diploma in 1923, which is given, after examination, to candidates who have undergone two years' training in selected institutes. A post-graduate course 'for more advanced specialization in research work' and for the ordinary men in the trade 'facilities for the acquisition of practical knowledge of the latest methods of work' have also been arranged.

In view of there being no indigenous breeds of dairy cattle with milk yield sufficient to make dairying a paying proposition, a great deal of earlier *cattle breeding* work was directed towards crossing Indian cattle with well-known Western dairy breeds. The results have been disappointing, and 'cross breeding as a policy for the general improvement of the cattle wealth of the country' has been found to be wholly unsuitable. Similar experiments at acclimatizing European cattle to Indian conditions and breeding them pure in the country have not so far yielded very encouraging results. The breeding of indigenous breeds, on the other hand 'by pure line selection with the definite objective of developing a high milk yielding strain' has proved very successful, and good herds of Sahiwal, Scindi, Hariana and Tharparkar, which compare very favourably in their milk yield with Western dairy cattle, have been established at different centres. Systematic breeding of the buffalo, the other milch animal of India, has improved the fat content of its milk by over 50%. Herd Books started recently for selected Indian milch breeds should prove useful in connection with future breeding work.

As most of the natural fodder in India is available only during the monsoon, a great deal of work has been carried out in selecting more profitable *fodder crops*. Cultivation of perennial grasses in irrigated areas and growing fodder crops in rotation have received a great deal of attention, and experimental work on silage operations has yielded valuable results. Detailed investigations have also been carried out on starch equivalents of various Indian foods, carotene contents of important fodders, mineral feeding of adults and calves, digestibility of coarse fodders, requirements of concentrates by dairy cows, etc., and a great deal of data collected—this should enable the dairyman 'to compute rations so as to be able to get the most out of the money spent in feeding his stock'.

Rearing and management have received a considerable amount of attention, and advances made in systematic breeding, overcoming late maturing and irregular breeding of various breeds, milking, standardization of lactation periods and other connected problems.

A great deal of intensive research has also been devoted to the production and handling of milk and milk products; and the Agricultural Produce (Grading and Marking) Act, 1937, is likely to provide the necessary 'incentive to the producers and traders to deal in improved quality products'.

Archæology

In a detailed review (pp. 255–299) Rao Bahadur Dikshit has discussed the progress of Archæology in India during the past twenty-five years. Reference is made in the introduction to the state of archæological studies in India prior to 1902 when Lord Curzon reorganized the Archæological Survey and appointed Sir John Marshall (then Mr. Marshall) as its first Director General. The inauguration of systematic excavations in India according to the scientific methods adopted

in Western countries, the preservation of monuments, the encouragement of epigraphical studies and the establishment and development of Archæological museums stand to the credit of Sir John Marshall. Excavations have been carried out at Rajgir, Sahet Mahet, Kasia, Sarnath, Mirpur Khas, Peshawar, Bhita, Basarh, Taxila, Pataliputra, Sanchi, Besnagar and Nalanda. Most of these sites, which were already well known, were referrable to a date prior to the birth of Buddha. In 1922-23 the discovery of Mohenjodaro in Sind opened a new vista of research, as it carried back the antiquity of Indian civilization to at least the Chalcolithic Period of about the third millennium B.C. Extensive excavations in connection with the sites of this period have been carried out at Mohenjodaro, and at Harappa in the Punjab while explorations have been carried out in Baluchistan and a preliminary prehistoric survey of Sind has also been completed. The increased grant available for excavation work also made it possible for the Department to extend its activities in Bengal, Bihar and the Madras Presidency.

The activities in the field have been responsible for the growth of archæological museums in the country. Among the new museums started during this period are the Central Asian Antiquities Museum at New Delhi, and the museums at Taxila, Sarnath and other sites of excavations. Numerous additions have also been made to the Archæological Section of the Indian Museum which has shown remarkable development during the last twenty-five years.

The preservation of monuments was, during this period, recognized as a charge of the Central Government, and since the Reforms of 1919 a systematic campaign has been undertaken by the Department to repair and maintain in good order the national monuments of India. A specially trained Archæological Chemist has also been engaged in the treatment of excavated objects and those housed in museums, and also on the analyses of various specimens to determine the compositions and technique of preparation of various materials such as metals, glass, glazes, faience, mortars, pigments, etc.

In the domain of *Epigraphy* may be noted the discovery of a large number of inscriptions of historical importance, such as the Edicts of Asoka in the Nizam's dominions, the inscriptions of the Ikshvaku dynasty from Nagarjunikonda, the copper-plate of a Vakataka queen, the Gupta copper-plate of Devapala, the Velurpalaiyam copper-plates of the Pallavas, the Brahmi inscriptions of the Madura and Tinevelley caves, the labelled portrait-statues of Pallava kings, the Alluru inscription and so on. These important discoveries have supplied various missing links, and as a result several disputed points of chronology have been settled, erroneous views corrected, and fresh information obtained, all of which has greatly extended our knowledge of the ancient history of India. Much has also been done for the decipherment and publication of Indo-Moslem inscriptions.

Considerable progress has been made in the study of *Numismatics*. The discovery of several hoards of punch-marked coins, which constitute India's earliest coinage, has shown that this form of currency was prevalent over the whole of Northern India and existed also in the South. The discovery of a large number of clay-moulds of Yaudheya coins near Rohtak in the Punjab has thrown important light on the method and technique of casting coins in ancient India. In the field of Kshatrapa and Gupta coins considerable advance has been made and similar progress is reported in the study of Muslim Numismatics.

Much of India's precious heritage is to be found within the domains of the Indian Rulers many of whom have followed a progressive policy in the matter of archæological research. In the premier state of Hyderabad, His Exalted Highness the Nizam founded an Archæological Department in 1914, whose greatest triumph is the work in connection with the preservation of the Ajanta frescoes. Similarly, Mysore and Gwalior have organized their Archæological Surveys. The former has undertaken excavations at the ancient site of Chandravalli and the latter at Padmavati, one of the capitals of the Naga kings of the third century A.D.

Anthropology

The progress of Anthropology in India during the past twenty-five years is reviewed by Dr. Guha (pp. 300–335). This period immediately follows an earlier era in which preliminary survey of the tribes and castes of India and the beginnings of more intensive studies of special groups of races in selected areas had been started on the lines laid down by Sir Herbert Risley. The earlier work of a general anthropological nature with a list of works dealing with the special areas and tribes is reviewed in an introductory section. The outstanding works in this connection published mainly during the period under review are (i) detailed studies on a number of tribes of the Naga Hills; these investigations, which cover almost an entire block of contiguous and closely related tribes, provide a fairly complete account of the stratification of the Naga cultures; and (ii) detailed work on the Austric-speaking people of the Central Belt, which has cleared up several important aspects of the social and religious institutions of these interesting tribes.

Prehistoric archæology has received considerable attention during the period. The discoveries, which brought to light the characteristic traits of the Indus Civilization of Chalcolithic times, resulted from extensive excavations carried out by the Archæological Survey of India at Mohenjodaro in Sind and Harappa in the Punjab. A Megalithic culture with a Neolithic basis has been discovered in the north-west of India, while a certain amount of work has also been carried out in Megalithic ruins of Southern India with which it would appear to be ultimately connected. Finally, mention may be made of the Stone-Age Culture as represented in the Soan Valley; this is essentially a flake culture

reminiscent of the Mousterian industry of Western Europe, and apparently was the source from which the Palæolithic culture of the Nurbadda Valley, Western Ghats and South India was derived.

During the period under review work on Physical Anthropology has been developed along two lines: (i) study of the skeletal remains of India's past population as recovered from various excavations of prehistoric sites, and (ii) somatic characters of selected groups of the present-day inhabitants of India.

The studies on the prehistoric human remains from the Indus Valley during the Chalcolithic times and Baluchistan have proved a close resemblance between the chief racial types recovered and those found in pre-Sargonic Mesopotamia. The Aditanallur (Madras Presidency) skulls have been found to be of two types; an Austroloid type, and second a more closely allied to the Armenoid.

A detailed survey of the *somatic traits* of the Indian races has made it possible, for the first time, to reconstruct a racial history of India. In this connection reference may also be made to the studies on the racial origins of the Indian peoples, the comprehensive researches on various sections of the population of Portuguese India, as also of the north, particularly of the Dardic tribes in the upper Indus Valley.

Within recent years, work has also been started on the *blood-group distribution* of various tribes and classes of India.

In *Cultural Anthropology* mention may be made of the analysis of the Indian caste system, marriage regulations as affected by contact of peoples, and the existence of a dual organization as the basis of the Dravidian social structure. Religion, folklore, magic, medicine and witchcraft amongst some of the primitive tribes have also been studied in detail in certain areas.

Psychology

Psychology, as Dr. Bose points out in his review (pp. 336–352), is the youngest of all sciences. It was only in 1905 that Psychology was allowed as a separate and independent subject for the post-graduate classes in the Calcutta University. Since 1916, however, psychological studies have been started in several of the Indian universities, and the psychological movement has made steady headway.

Various new instruments have been devised by different workers for experimental work in psychology; of these the exposure apparatus, ergograph and æsthesiometer may be specially mentioned.

Most of the research work carried out in India during the period under review concerns specific problems, such as emotions, instinct, consciousness, problems of errors and illusions in the domain of perception, learning and memorization, reaction-time reflexes, child education, intelligence, etc.

Social psychology and *group psychology* have attracted a number of workers. The importance of industrial psychology has been

stressed in several recent contributions, and the problem of fatigue has been investigated in some detail.

In the domain of *abnormal psychology* valuable work has been carried out on the different aspects of abnormalities in children and the effect of parental behaviour on their mental constitution, dementia præcox, pykenolepsy, suicide, sexual reciprocity, etc. On the basis of psychoanalytic case records a new theory of mental life has been advanced in which repression, ambition, conscience and other mental mechanisms are explained on the 'basis of conflict between wishes of the opposite type'.

Studies have been directed to elucidating the history of psychology in India, with particular reference to the findings of ancient Indian philosophers; the place of psychiatry in India has also been discussed in two important contributions.

Zoology

Dr. Rao in his review (pp. 353–433) has described in detail the progress of zoological research in India during the last quarter of a century. The outstanding achievements of the period may be said to be (1) the establishment of properly equipped Zoology Departments in most of the Indian Universities, (2) the official recognition accorded to Zoology by the Government of India by the foundation of the Zoological Survey of India in 1916, for extending the knowledge of the geographical distribution of animals in the country by survey work, maintaining and looking after the National Zoological Collections in the Indian Museum, Calcutta, and acting as the Bureau of Systematic Zoology for the Indian Empire, (3) the organization of special Mammal and Bird surveys in the hitherto unexplored or little-known regions of the country by the Bombay Natural History Society, (4) the realization of the importance of zoological research and its application to the elucidation of problems connected with medical and veterinary sciences on the one hand and agriculture, forestry, and fisheries on the other, and (5) the oceanographical studies leading to an increase in our knowledge of the physical conditions governing the life of marine animals in the surface waters of the Bay of Bengal and the Andaman Sea.

The first achievement has resulted in a fairly wide dissemination of zoological knowledge and organization of research under the auspices of universities. Owing, however, to limitations in the way of literature, reference collections, etc., such research has been confined chiefly to morphology, taxonomy, and cytology of animals which are found abundantly within easy reach of the university centres. The morphology of the Vertebrate groups, and the taxonomy of Oligochætes, Helminths and Protozoa, and the cytology, more particularly gametogenesis, of various Invertebrate animals have received considerable attention. The difficulties experienced in following text-books of foreign origin in practical classes working with Indian species of animals as types for study led to another important development in the history of Indian Zoology, namely, the

preparation and publication in India of a series of detailed Zoological Memoirs on some of the commoner types of Indian animals used in various Indian laboratories.

The work of the Zoological Survey of India has led to a considerable increase in our knowledge of the Indian fauna, more particularly of the Invertebrate groups of animals, both in regard to their taxonomy and geographical distribution. The groups which have received most attention during the period under review are the freshwaters sponges ; coelenterates and polyzoa ; fresh- and brackish-water mollusca ; crustacea, chiefly the fresh- and brackish-water crabs and prawns, and the copepods of the Indian seas ; insects belonging to the orders Diptera, Ephemeroptera, Coleoptera, and Rhynchota ; freshwater fishes of the torrential streams, lakes and ponds, Batrachia and Reptilia. These have been studied with special reference to their habitats in different parts of the country. The structural modifications following adaptations to the peculiar conditions which prevail in these habitats and their bearing on taxonomy have also received attention.

The work carried out by various specialists on Indian birds and mammals in the nineteenth and early part of the present century had revealed wide gaps in our knowledge of the distribution of these animals. The surveys begun under the auspices of the Bombay Natural History Society have helped considerably to bridge these gaps and introduced new criteria for the classification of birds and mammals. The trinomial nomenclature adopted for the birds and the revised *Fauna* volumes on this group is but one of the results of the detailed study of the avifauna of the country. The revised volumes on Mammalia in the *Fauna* series, which are expected to be published shortly, will embody similar modifications in the taxonomy of mammals and should add considerably to our knowledge of their distribution and of the inter-relationships of closely allied forms.

The extent to which zoological knowledge is being applied to the elucidation of the problems of disease and destruction of human beings, animals, and plants in India is reflected in the growth of specialist institutions like the Imperial Council of Agricultural Research, the Imperial Veterinary Research Institute, the Imperial Forest Research Institute, the School of Tropical Medicine and the All-India Institute of Hygiene, the Central Malaria Research Organization, the Indian Lac Research Institute, the Locust Research Organization, etc., which have been established during the last quarter of a century or so. Within recent years Protozoologists, Helminthologists and Entomologists have taken an ever-increasing share in the work of these institutions.

As a result of detailed investigations in European waters it has been definitely established that the prosperity of the Marine Fisheries is entirely dependent on the planktonic population of the sea water, and this in turn is determined by the physical conditions

of the surface sea water. The study of these conditions for the first time in Indian waters, particularly of the Bay of Bengal, and other oceanographical research carried out by the Surgeon Naturalist to the Marine Survey of India have greatly advanced our knowledge of the hydrography of the Indian seas during the quarter of a century following the inauguration of the Indian Science Congress.

Forestry

Mr. Champion in his review of the progress of Forestry in India during the past twenty-five years (pp. 434–456) remarks that this period was ushered in by the opening of the Forest Research Institute building at Dehra Dun in 1914, as a result of which the progress made during this quarter of a century has ' been far greater than that seen by any previous quarter-century '. To meet the increased demands for research and investigations in reference to Forestry a new institute was found necessary and was completed in 1927. In four branches—Utilization, Botany, Entomology and Chemistry—the major part of the programme of research on Indian Forestry drawn up in consultation with the provinces, is centralized at the Research Institute. In Silviculture, on the other hand, the main research is carried out by provincial agencies and only the important work of collation and standardization is carried out by the Central Silviculturist at Dehra Dun. The arrangements for forest education in India both in regard to senior training courses at the Forest Research Institute, Dehra Dun, and the subordinate courses at the Ranger College, Dehra Dun, and the Madras Forest College at Coimbatore are briefly mentioned.

Silvicultural research in the provinces has progressed at a fairly rapid rate and, except for the provinces of Bombay and Sind, there are at present whole-time Silvicultural research officers in all provinces. At the Central Institute statistical work has been thoroughly standardized, and Yield and Volume Tables for *Shorea robusta*, *Pinus longifolia*, *Cedrus deodara* and *Quercus incana* have been drawn up. Attention has also been paid to the experimental work connected with regeneration and recent years have seen ' the application of statistical methods to an ever-widening field of experimental results '. Another recently completed task is the preparation of preliminary statistical surveys and descriptions of the main types of forests in India.

Botanical research in connection with forests has consisted in determining the soil factors connected with natural regeneration of *Shorea robusta*, and the preparation of Forest Floras; the latter are now available for practically every province. In the mycological field, studies have been carried out on various important parasitic and saprophytic fungi, and a considerable amount of research has been devoted to the spike disease of the sandalwood tree.

In *Forest Entomology*, a great deal of work has been done on the more serious pests of timber trees, notably of *Shorea* and teak,

many defoliators and on the insect vectors of the spike disease of sandal.

In *Forest Chemistry* investigations have been concerned mainly with wood preservatives, minor forest products such as drugs, essential oils and soils.

Research on regeneration problems, both natural and artificial, has resulted in the development of special types of plantation work known as the 'Rab' and 'Taungya' methods. These methods enable plantation work to be carried out far more successfully than was hitherto the case. Problems in reference to thinning of plantations, pruning of lower branches, forest fires and browsing in relation to regeneration have also been investigated.

A great deal of work has been devoted to silvicultural systems, preparation of working plans and utilization research, all of which show the great advance made in the domain of Indian forestry during the past quarter of a century. The reviewer definitely attributes a considerable proportion of this progress to 'a more scientific outlook in keeping with the trend of the times, as reflected by the provision for systematic research which has taken place during the period'.

Engineering

The progress of Engineering in India during the past twenty-five years is reviewed by Mr. Ash in two sections (pp. 457–574). An introductory section is followed by a description of engineering projects and schemes carried out and reference is made to the research work in connection with the solution of problems that were encountered in the carrying out of such projects, while the next section deals with special experimental work, research and investigations in connection with various engineering problems.

The major part of the first section of the review deals with *irrigation engineering* in which class India stands pre-eminent. The expenditure on the great irrigation schemes of India has been of a colossal nature, but so also have been the benefits which India has derived from these stupendous enterprises. In connection with various schemes is discussed the application of some important research work, which has afforded to those responsible for the execution of the schemes much valuable guidance regarding the lines on which to plan their projects. Special reference in this connection may be made to the storage reservoirs and weirs-controlled schemes in Bombay and Madras, the Triple Canals Project in the Punjab, the Lloyd Barrage Project in Sind and the Hydro-electric Schemes for utilizing sub-soil water in the United Provinces. In order to study and co-ordinate research work on irrigation problems of an all-India nature a Central Board of Irrigation was constituted in 1925, while a Central Information Bureau was established some years later as a result of the recommendations of the Royal Commission on Agriculture in India. The Board is now able not only to deal with questions of administrative and

technical importance, but to formulate research and technical schemes, and 'keep agricultural officers and the public generally in touch with irrigation developments in India and abroad'.

The developments which have taken place in connection with the *Indian railways* are described at some length. The great increase in the route mileage and the number of great bridges constructed in connection with new railway projects are indicative of the great progress that has been made in the expansion of India's transport facilities. An extensive amount of research has been carried out in connection with various railway problems, such as the dynamic effects of trains on bridges, pre-stressing girders with the resultant economy in design, electric arc-welding of bridge and structural steelwork leading to important schemes of bridge strengthening, investigations in connection with the improvement of track materials, standardization of locomotives, etc. Steady progress has been maintained in mechanical railway engineering technique during the past twenty-five years, and various Standardization Committees working in conjunction with the Central Standardization Officer of the Railway Board have been able not only to bring about improvements in the existing materials, but to investigate the possibilities of fresh materials and new processes.

The great progress in the field of *electrical engineering* is reflected by the extensive Hydro-electric projects, which have been carried out; these are and will be of immense importance in developing India's resources.

The period under review has marked considerable expansion in the major *ports* of India, and the sub-section on Ports and Harbours contains a succinct account of the developments in the older ports and the construction of the two new major ports which have been brought into being during the period under review. All this work has involved a great deal of research. In the case of the Rangoon Port important investigations in connection with control of the Rangoon River have been carried out, while the measures adopted, after careful investigations, for saving the Hardinge Bridge over the lower Ganges mark an 'outstanding feature of River Engineering work' in India.

In *bridge building*, great advances have been made in designing, construction of sub-structures and piers, the manufacture of bridge steel work, etc.

Experimental work, research and investigations during the period under review are described under three main heads: (1) irrigation, (2) marine, and (3) stresses in steel structures.

In connection with irrigation, detailed researches have been carried out on measuring porosities of soil *in situ*, soil surveys, rise of the sub-soil water, laws of sub-soil flow under works on permeable foundations, draining and reclamation, fluming, silt in the economy of a canal system, river models, etc., and a great deal of very valuable data collected. In connection with marine work,

studies of tidal models for the Port of Rangoon and for Bombay Harbour have greatly elucidated the problems encountered. Investigations of littoral drift at Vizagapatam resulting from wave action carried out on a large scale model enabled the authorities to determine the best alignment, length, shape and position of the breakwater which was constructed for the protection of the harbour.

An instance is quoted of the co-relation, in practice, of the results of Professor Hardy Cross's recent 'Column Analogy' with those obtained by the application of Pippard and Sparkes's experimental methods, in connection with the design of a heavy steel structure.

Physiology

In his review of the progress of Physiology in India during the past twenty-five years (pp. 575–630), Lt.-Col. Bhatia indicates the main lines of work carried out with a view to giving a general idea of the special fields that are being investigated. A great deal of attention has been devoted to racial physiology for obtaining normal physiological data regarding the inhabitants of the country. Such investigations have been carried out in reference to blood and its constituents, basal metabolic rate, vital capacity, gastric juice composition, nutrition problems, etc. Investigations of this character are of special importance from the point of Human Physiology, and the data already collected are gradually building up the foundations for a proper understanding of racial physiology in India.

Extensive investigations have been carried out on the cytology and chemistry of *blood*. Several workers have estimated the constituents of blood, such as blood-sugar, cholesterol, hæmoglobin and reticulocyte percentages, etc. Biophysics and Biochemistry of blood have received considerable attention, in particular reference to tuberculosis, and investigations have been carried out on the hæmoglobin percentages of healthy individuals of certain parts of the country. Similar research has been devoted to coagulation and serum calcium content of blood, and the effects of various drugs have been investigated.

Electro-cardiographic studies have shown that there is no appreciable difference in the various wave amplitudes and time intervals of the normal individuals investigated from the accepted Western Standards. Reactions of the heart to drugs have been investigated in great detail, and as a result certain definite laws governing the normal beating of the heart and its behaviour under artificial stimulation formulated.

Investigations on the normal standards of *Vital Capacity* of Indians have shown that the figures obtained are generally lower than those accepted as standards for Europeans and Americans. The importance of carbon dioxide in the phenomena of circulation and the effects of intra-venous injection of oxygen on circulation have been studied.

Studies on the resting *gastric juice* of Indians show a lower total acidity and a lower percentage of free hydrochloric acid. Repeated observations on the same subject exhibit a marked variation in the quantity of the juice, bile, free hydrochloric acid and total acidity. Work has also been done on variations in the gastric acidity after a test meal. Similar studies have been carried out in reference to blood-sugar, respiration rates, blood pressure and other factors. Figures for basal metabolic rate in Indians have been found in most parts of the country to be definitely lower as compared with those of the inhabitants of temperate climates. The ætiological factors in diabetes melitus have also been worked out in some detail.

Large numbers of workers have interested themselves in studying problems relating to *diatetics* and *nutrition*. Diet surveys have been carried out in several parts of India, and it has been found that the lack of certain protective constituents in the diet, such as good protein and certain vitamins, specially A, B and D, is responsible for poor bodily nutrition in most cases. Experimental work on vitamin deficiency also deserves special mention. The problem of glycosuria has attracted much attention. Owing to the excessive ingestion of sugar and starch, it has been found that the tolerance for carbohydrates in strict vegetarians is relatively poor. The deficiency of Vitamin B has been considered to be responsible for macrocytic anæmia, while the deficiency of Vitamins A and C and excess of calcium in the diet are probably associated with the formation of stone in the bladder.

Important work on the action of acetylcholine and choline extrase has been carried out, and from a study of the reactions of the heart to various drugs certain laws governing the activities of the rhythmically active tissues enunciated. Extensive researches have also been carried out in *Physiological Chemistry* and valuable data collected.

The efficiency of the kidneys of Indians to concentrate urea has been found to be just as high as that of Englishmen, but the average percentage of urea in urine appears to be lower.

In the field of *endocrines*, the influence of adrenaline, pituitary extract and insulin on the movements of the intestine, the action of insulin on normal and diabetic hearts, gonadal extracts as antidiabetic remedies, etc., have been investigated. Important researches have been carried out on the size of the thyroid gland and the extent to which it is influenced by 'sex, sexual activity, season, sanitary conditions and iodine supply'. The ætiology of goitre has been extensively studied, and considerable evidence accumulated to show that it is a water-borne disease. Inter-relationships of hormones have been studied in some detail, and it has been suggested that they are all intimately associated with each other, and that there is an 'integration of hormonal functions by virtue of this mutual interdependence'.

Pharmacological research has developed at a rapid rate since the foundation of the School of Tropical Medicine, Calcutta. Detailed investigations have been carried out on the pharmacology and toxicology of a large variety of remedies, such as cinchona alkaloids, emetine, organic derivatives of antimony, etc., which are of special importance to medical practice in India. The pharmacological action of the venoms of Indian snakes and the physiological and biological properties of blood sera in health and disease have been studied and the subject of Drug addiction in India has been investigated. Special attention has been paid to indigenous drugs, and within recent years work on the biological standardization of drugs has also been initiated.

Medical Research

In the review of the progress of Medical Research in India during the past twenty-five years contributed by Sir Upendranath Brahmachari (pp. 631–673) a brief account is given of the work carried out in connection with the principal diseases prevalent in India, their ætiology and treatment by up-to-date methods, in several cases evolved as a result of intensive research in the country. In spite of various adverse circumstances considerable advances have been made, and the contributions to the knowledge of the various factors 'that affect the health and well-being of the people have not been small during the past twenty-five years'.

As a result of extensive research the knowledge of the ætiology of *cholera* has materially increased. Various types of cholera and para-cholera vibrios have been investigated and classified according to their agglutinability and chemical structure based on analyses of their carbohydrate and protein fractions, etc. Bacteriophage, which has been found to play an important role not only in the epidemiology of cholera but also in its cure, has received a considerable amount of attention, and according to their lysability several types, A–F, are now recognized. The anti-cholera vaccine, originally prepared by Haffkine, has been extensively tried, with promising results. Epidemiology and periodicity of cholera also have received considerable attention.

Plague is caused by an epizootic which is parasitic in certain species of rats. Plague in rats is a septicæmia, and is transmitted from infected to healthy rats and man by the bites of parasitic fleas of rats which become infected by ingesting the blood of their host. The rôle and importance of the different species of rats and fleas in the epidemiology of the disease have received considerable attention, and factors responsible for the appearance and spread of the disease under various climatic conditions elucidated. Effective measures for the destruction of rats have been experimented upon. For the immunization of susceptibles the vaccine, originally prepared by Haffkine, but standardized and greatly improved since, has proved very useful. Latest researches in this connection have

resulted in the preparation of a potent anti-plague serum; this, however, has not so far been tried extensively in the field.

The work on *malaria* during the period under review has been devoted to various aspects of its epidemiology, entomological aspects, malaria surveys, forecasts of epidemics, relation of malaria to irrigation, hill malaria, malaria and bonification in deltaic areas, etc. For prophylactic work and treatment, quinine and other anti-malarial preparations have also been subjected to extensive experimental work. Investigations have been carried out on the prophylaxis of *blackwater fever*, and our knowledge of the ætiology and treatment of the disease has materially advanced.

During the period of the review much advance has been made in India in the discovery of the mode of transmission and successful treatment of *kala-azar*. The sandfly, *Phlebotomus argentipes*, has been proved conclusively to be the transmitter of the disease. This sandfly was successfully infected with parasite of kala-azar and though hamsters have been infected by the bites of such sandflies, all attempts experimentally to transmit infection from such flies to man have so far been unsuccessful. Advances have been made in the diagnosis of the disease by means of liver and spleen punctures, and various specific reactions such as globulin opacity test, globulin ring test, aldehyde and urea-stibamine tests devised. The treatment of kala-azar by means of specially potent therapeutic antimonials discovered in India has very materially reduced the incidence of the disease in certain provinces, notably Assam. A peculiar skin lesion named 'Dermal Leishmanoid' has also been the subject of a certain amount of research.

The clinical manifestations and ætiology of *epidemic dropsy* have been subjected to extensive research, and various theories such as the rice, mustard oil and infection-contagion theories have been investigated; but no single theory seems so far sufficient to explain the causation of the disease.

In India two types of infection of *filariasis*, caused by two distinct species of Filariæ, have been found. The exact distribution of the two types and their transmission by mosquitoes of the genera *Culex* and *Mansonioides* respectively have been fully elucidated. Considerable research has also been carried out in the treatment of the disease; but no satisfactory results have yet been achieved.

Our knowledge of *leprosy* and its treatment has materially advanced, and it is hoped that with proper detection and treatment of the disease, the time is not far off when this greatly abhorred disease will be fully controlled, if not entirely stamped out, in India.

A great deal of work has been done on dysentery, typhus, relapsing and sandfly fever, dengue and cerebro-spinal fever. Not only have the causative agents and various other factors connected

with the diseases been investigated in detail, but their treatment also has received a great deal of attention.

Rabies, snake-venoms and anti-venenes have been the subject of research at various centres.

The epidemiology and pathology of *tuberculosis* have been investigated. It has been proved that bovine tubercle bacillus, which is responsible for the causation of a fair percentage of pulmonary and non-pulmonary tuberculosis in Europe, is not of much importance in this country. Rheumatism and heart disease which, according to earlier views, did not occur in India, have been found to occur, though they are probably not so common as in England.

Research work in connection with the *diseases of nutrition* has been directed to investigations on the nutritive value of Indian food-stuffs, composition of Indian dietaries and their relation to health and deficiency diseases.

Detailed enquiries have been instituted on several drugs used in indigenous systems of medicine, and the active principles of a number of these isolated and investigated.

Finally, Sir Upendranath refers to the very important part played by the Indian Research Fund Association in the prosecution and advancement of medical research in India ; the various medical research institutes have also been responsible for a great deal of valuable work. All these agencies, however, are not sufficient for the needs of India, and the reviewer puts forward a strong plea for the establishment of a properly endowed and equipped Federal Institution for medical research.

Physics

The progress of Physical Research in India during the past twenty-five years is reviewed (pp. 674–741) by Prof. Saha with the help of a number of collaborators. In the review he gives a connected account under 12 main headings of the results achieved in various branches of Physics during the short period since the study of Physics in India has been organized on proper lines. With the establishment of the University College of Science, Calcutta in 1915, and the gradual development of physical laboratories in other universities of India physical studies progressed at a very rapid pace. Various Government scientific departments and independent research institutions, such as the Indian Association for the Cultivation of Science, and the Bose Research Institute, Calcutta, the Indian Institute of Science, Bangalore, etc., also materially helped in advancing the cause of Physical Science.

Important researches in *acoustics* have been carried out during the period under review. The theory of Bowed Strings, vibration in air due to impinging spheres, the position of nodal lines in percussion instruments, etc. have been investigated, mainly due to the influence of Sir Venkata Raman's earlier work. Research has also been devoted to the art of finger playing on Indian stringed instruments, sound control and velocity of sound.

In theoretical *astrophysics*, Indian investigators have achieved great distinction. About the year 1920-21 Saha published his theories of thermal ionization and radiation, and worked out the first successful physical theory of Stellar Spectra. The start so happily given to theoretical astrophysics has been continued by Chandrasekhar, Kothari and Majumdar on problems connected with atmospheres of stars, application of Fermi-Dirac statistics to elucidation of the internal structure of stars, and to Kothari's theory of pressure of ionization. The problem of Relativistic Cosmogony has been studied in detail by a number of workers. The two astronomical laboratories in the country have been engaged in important astrographical, astronomic and meteorological investigations.

Researches in *Chemical Physics* have been mainly devoted to the extension of Franck's interpretation of absorption spectra of alkali halides to other compounds, origin of the colour of inorganic salts, absorption spectra and valency of a large number of polyatomic molecules and complex salts, band spectra, etc. A general theory advanced to explain active nitrogen phenomena has led to a great deal of theoretical and experimental work.

Extensive investigations have been carried out in magneto-chemistry, paramagnetism and allied subjects.

Most spectacular advances have been made in *Optics*. Detailed studies on Diffraction phenomena resulted in the discovery of the well-known *Raman Effect*, which has not only brought fame to its discoverer, Sir Venkata Raman, but gained international recognition for Indian Science. Researches in connection with this phenomenon have been directed to the elucidation and experimental verification of the theory, experimental technique, investigations on the chemical constitution and structure of the molecules, effect of change of state and other physical conditions on the phenomenon and finally the origin of modified continuous line spectra which are generally observed in the Raman spectra of liquids and solids respectively.

Much valuable work has been carried out in connection with Radio-activity of rocks, hot springs and of the atmosphere, investigations on α and β particles, absorption and scattering of γ-rays and Cosmic and Positive rays.

Spectroscopy has also attracted a fair number of workers and a large number of series spectra have been investigated. The hyperfine structure of spectral lines has also been studied.

Considerable amount of attention has been devoted to *Theoretical Physics*, and in this connection reference may be made to S. N. Bose's fundamental work known as Bose-Einstein Statistics.

Wireless research, though started only as late as 1928, has led to the important discovery of D and C layers of ionization lower than the permanent Kennelly-Heaviside layer. Studies on the ionospheres are now being carried out at a number of centres, particularly at Calcutta and at Allahabad.

A fair amount of work has been carried out on X-Rays in reference to diffraction, analyses of organic crystals, etc., while theoretical studies have led to important conclusions.

In *Meteorology* very valuable results have been achieved in connection with daily weather and seasonal forecasting. Special techniques have been evolved for the investigation of the Upper Air, and research has been carried out on the structure and movements of tropical storms, depressions, etc., in the Indian seas. Radiative and connective processes in the atmosphere have also been investigated.

Botany

In the review of the progress of Botanical Research (pp. 742–767), Professor Agharkar deals with the work carried out during the years 1910 to 1935. Prior to this period the botanical work in India consisted chiefly of systematic, geographical or economic studies carried out by four provincial Botanical departments. An All-India Botanical Survey of India was founded in 1899 to co-ordinate the work of these departments and to survey the outlying little known areas. A few botanists had been employed from time to time in some of the colleges, but in general the facilities for the teaching of Botany and more particularly for research in the subject were strictly imited. According to the reviewer, the conditions have changed very materially during the period under review, 'due to the establishment of teaching and research departments in the universities and colleges .... mainly during the post-war period'.

Recent morphological work in India has not been confined to mere records of abnormalities and variations from the normal structure, studies on the floral biology, methods of pollination, fruit dispersal, etc., but has also been directed to investigations on the internal anatomy, life-histories and embryology of different plants. Special reference in this connection may be made to the work on the physiological anatomy of the plants of Indian deserts, halopytes and climbing plants. Embryological studies have been directed towards the elucidation of the development of ovules, embryo-sacs, etc., and the life-histories of plants of various families.

Teratological work has consisted in the descriptions of abnormalities of various Phaneorgams, and studies of plant galls.

Physiological research has been actively pursued. The late Sir Jagadis Bose and his collaborators laid great stress on the vitalistic activities of the life-processes of plants, but this view has not been supported by other workers, particularly in so far as the absorption and ascent of sap is concerned. Researches have also been carried out on the nature of protoplasm, absorption of ions by plants from cultures, kinetics of photosynthesis, plant-metabolism, nitrification of soils, etc.

Our knowledge of Indian Algæ, though far from complete, has been greatly added to by work done during the period. The same may be said to be the case with Fungi. In spite of a great

deal of systematic work, Butler and Bisby estimated that probably not more than about 10% of the Indian Fungi had been recorded up to 1931.

Reference may here be made to the very important work on the annual recurrence of cereal rusts in the plains of India, which is now believed to be 'due to windblown urodospores disseminated from the hills where they over-summer'. This view, if confirmed, would make it possible to control these rusts in India more easily than in other countries.

The systematics of Indian Lichens, Liverworts and Mosses have attracted a fair number of workers, and as a result these forms are comparatively much better known.

Thanks to the work of early pioneers like Beddome, Clarke and others, our knowledge of the Indian Pheridophyta is also comparatively speaking much more complete. During the period under review advances have been made in regard to the description of new species and their distribution in various areas, while several authors have studied the anatomy and life-histories of some species. The study of this group in general is, however, greatly hampered by the absence of proper facilities for the cultivation of these plants in the botanical gardens.

Considerable progress has been made in our knowledge of the life-history and distribution, both present and past, of the Indian Angiosperms; similarly studies on the morphology, anatomy, embryology, physiology, ecology and distribution of the Indian flowering plants have made a fair headway.

Most important advances have been made in Palæobotany, in which the results obtained are already being employed for the determination of the age of some of the geological formations, such as the Deccan Trap.

Great attention has also been paid to studies in Applied Botany, and valuable results have already been achieved in reference to Forest and Agricultural Botany, while our knowledge of the indigenous medicinal plants has materially increased within recent years.

Considerable amount of work has been carried out on Plant Geography, and a great deal of valuable information is now available regarding the distribution, relations and ecology of the plants of different parts of India.

In conclusion the reviewer refers to the urgent need for a peoperly constituted National Herbarium, and greater attention being paid to ecological and pharmacognosic studies.

V. Concluding Remarks.

Professor Thomas [1] sums up the glorious past of the Educational System of ancient India as: 'Education is no exotic in India. There

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[1] Thomas, F. W.—*The History and Prospects of British Education in India*, p. 1 (London, 1891).

is no country where the love of learning had so early an origin or has exercised so lasting and powerful an influence'. Reference has already been made to the fact that from about the close of the 12th to the middle of the 19th century there was a long interval of intellectual stagnation in the country, but with settled conditions of life and Government and the provision of facilities for education the position changed materially. During the latter half of the 19th century there was a slow but steady progress of Western education, while in the first decade and a half of the 20th century higher education, particularly, advanced at a very rapid rate. Scientific education also, in which a start had been made in the latter half of the previous century, gradually began to assume its proper position in the educational system. The Government Scientific Departments and research institutions were organized on a more extensive basis, and a number of scientific societies, culminating in the foundation of the Indian Science Congress in 1914, were started. The World War, though it slowed down the progress, brought to the fore the importance of scientific education, and research, and there was a great advance in the organizations for scientific education and research in the years immediately following it. The scientific and research departments of the Central and Provincial Governments were greatly enlarged and several special research institutions were founded. Most of the universities instituted courses for advanced studies and special Honours courses in scientific subjects, and by new appointments, extensions of libraries and laboratories materially advanced the cause of original research. Public support for the pursuit of science was rather limited, but a few important endowments resulted in the establishment of a number of scientific organizations both for teaching and research. Even with the rather limited facilities, the Indian students of science have during the short period of a quarter of a century justified their capacity for original investigations, and in the words of the late Lord Rutherford 'India is now taking an honourable part and an ever-increasing share in the advance of knowledge in pure science'. Reference may here be made to the great services rendered by the Indian Science Congress Association to the cause of Science in India by affording a common meeting ground for the discussion of scientific problems and by bringing to the notice of the Government and the public the importance of science and scientific research for national advancement.

In his presidential address [1] to the Jubilee Session of the Indian Science Congress the late Lord Rutherford summed up the situation as regards scientific education in India as follows:—

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[1] Presidential Address of the late Prof. the Rt. Hon. Lord Rutherford of Nelson for the Twenty-fifth Indian Science Congress Silver Jubilee Session, Calcutta, 1938 (received after his death). Published by the Royal Asiatic Society of Bengal.

'the universities of India have in later years made substantial progress both in teaching and research in science, yet it must be borne in mind that still greater responsibilities are likely to fall on them in the near future. This is in a sense a scientific age where there is an ever-increasing recognition throughout the world of the importance of science to national development . . . . . It is natural to look to the universities and technical institutions for the selection and training of the scientific men required for this development. In India, as in many other countries, there is likely to be a greater demand in the near future for well trained scientific men. With the growth of responsible government in India, it is to be anticipated that the staff required for the scientific services in India and for industrial research will more and more be drawn from students trained in the Indian universities'. These men will be the future leaders of research both in the Universities and in the scientific research organizations, and for their proper training it seems essential that the defects in the present-day system of education should be remedied at as early a date as possible. If the research work is to be of real and lasting value, it must be carried out in the interest of the country as a whole and not of any particular province or area. This necessitates careful planning and co-ordination of various schemes for research in all branches of science, whether pure or applied. In formulating the future policy, India should profit by the experience of Canada and Australia where the working of the scientific departments of the State or Provincial Governments *vis-a-vis* those of the Central or Federal Government has shown 'that the research organizations of the country should be truly national and responsible to the Federal Government alone. Even in an Empire the size of India, where the resources and needs of various provinces are widely different, it would seem that centralized organization of research is the only way of avoiding waste of money and effort. The detailed planning of research must be in the hands of those with the necessary specialized knowledge, and they must be able to act without suspicion of political or racial influence'[1].

A review of the past and present conditions affecting the progress of Science in India clearly shows that for a proper and efficient performance of the functions of scientists, as outlined in the above quotation, the constitution of an independent body of properly qualified and experienced men is essential. In other words, a plea is made for the foundation in India of a National Research Council on the lines of the body which ever since its constitution has been rendering such useful service in Great Britain. The functions of this Council should not only include the defining of scientific policy but it should also act as an expert advisory body for planning and co-ordinating all scientific research in the country. The planning of scientific policy and co-ordination of research should be so arranged

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1 *Nature*, vol. 141, No. 3557, p. 2 (1938).

as to preclude duplication and avoid wastage of talent and available funds, but without restricting the normal work of the universities, scientific departments and institutions, or in any way curbing individual initiative which is so essential for high class research. Such an authoritative body should also be able to help in bringing about the necessary reforms in the existing system of scientific education. In order to ensure that the work of the Council is not hindered by any extraneous circumstances and that the steady progress of scientific work, so essential in the cause of the advancement of the country, is maintained, it should be liberally endowed by the Central and Provincial Governments and by the public so as to be independent of annual appropriations for the carrying out of its programme of work. The above functions are somewhat similar to the objects of the National Institute of Sciences of India founded at Calcutta in 1935, and probably the existing machinery of the National Institute could easily be transformed to take on the functions of the proposed National Research Council of India.

PROGRESS OF SCIENTIFIC EDUCATION IN INDIA DURING THE PAST TWENTY-FIVE YEARS.

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Contents

I. Secondary School Section.

Scientific Education in this country is very far from being satisfactory. This is not surprising when one remembers that it is only during the last 25 years or so that even in the West, where organized education has developed very much more fully than here, reasonable attention has been paid to the claims of the Sciences for inclusion in the normal educational scheme. Traditions die hard, and even in the most advanced countries there are many people who regard the inclusion of technical and scientific education in the school and college curriculum as unfortunate. To such minds education connotes merely the acquisition of a knowledge of the classics so as to produce that indefinable asset known as culture. To make their case strong these people define culture in their own terms. It was only because of the rapid progress in industrial and technical developments that authorities in the West were compelled to realize the utilitarian value of education and the necessity for adequate preparation on technical and scientific lines in educational institutions. In the first place, very few people pleaded for the introduction of science for its own sake, and the cultural values that should be attached to satisfactory scientific teaching were regarded as non-existent. These values are now of course recognized, but in the early days it was the commercial and industrial demands for a more efficient preparation that persuaded authorities to provide more adequately for scientific education in schools and colleges. This factor, namely the demand arising from the industrial and technical needs of the country for an education which fitted people for their practical work in adult life, has been very largely absent in India.

The development of facilities for instruction in the sciences in Schools and Colleges in this country has come as much from an imitation of the West as from any natural development arising out of the country's own needs. It is true, of course, that especially during recent years the backwardness of India's industrial development and the increasing demand for more outlets for the unemployed have resulted in greater attention being paid to scientific studies. Conservatism is however still extremely strong. It is not yet realized that even from the point of view of pure educational idealism science provides as efficient a means of ensuring satisfactory cultural and educational development as do the older classical subjects. The failure to realize the educational importance of scientific study is evidenced by the fact that as far as schools are concerned, with a few exceptions, scientific education is either altogether non-existent or at a very low stage of efficiency. It is necessary, if one wishes to understand the correct place of scientific studies in any educational institution, to draw a sharp distinction between scientific education and the imparting of scientific knowledge. The one implies the training of the intelligence and an appreciation of the laws which are at work in the natural world. It gives an understanding of the material forces and the material world, and should create an interest not only in the external world with which the pure sciences are usually concerned but also in the reaction of that world upon human life and human behaviour. Scientific education can be so developed and so organized as to be directed towards the development of understanding rather than to an accumulation of facts. In so far as it provides the mind with a background of knowledge and an understanding of scientific laws which remain with an individual throughout life stimulating his interest in the world around him, and enabling him to comprehend behaviour material and human, such an education has more cultural value than any acquaintance with the dead languages of a for-ever-departed past, however intimate that acquaintance may be. On the other hand, scientific education can be, and is, unfortunately, very frequently the mere imparting of knowledge and technique which has a direct application to certain practical aspects of industrial and commercial developments. This, of course, is of value, but is an aspect of education which has very little appeal for the conservative minded educationist.

It is now generally acknowledged that any education which fails to develop understanding and intelligence and merely consists of the acquisition of a knowledge of facts is sterile. It may and does have its place in technical institutions and those educational schemes which are a direct preparation for employment. Its place in the general educational scheme which should be applied to most immature minds is difficult to justify. To those who have given much thought to the subject the teaching of science will

probably be regarded as having a dual function. It is, if properly given, a natural cultural educational asset, and at the same time it gives the foundation upon which a satisfactory practical scheme of life can be built. It is the first, and I think the more fundamentally important aspect of scientific training that really matters in schools. If science is to have any value other than a purely utilitarian one, if it is to give a deeper understanding of the forces of nature at work in the world around us, if it is to create a more pleasurable interest in the surrounding world—human and material—then it is essential that it should not only form an integral part of any educational scheme developed subsequent to the acquisition of powers to read and write, but that it should be taught with these objects in view. It has now been generally recognized in the West that even for the students who intend when they proceed to the Universities to follow a classical or other non-scientific course, school education must include teaching upon the general principles of science as they find expression in an elementary knowledge of such subjects as Physics, Chemistry, Biology, Botany, Physiology, Astronomy, etc. Consequently in contemplating any extension or reformation of the scientific education in India, while one is appalled at the magnitude of the problem of introducing satisfactory scientific teaching in pre-University education, one must face the fact that unless this problem is solved, not only will any material improvement of University standards be impracticable but the general educational scheme must remain unsatisfactory. At the present moment many—probably the majority—of our Science Graduates, while they may have certain scientific knowledge have very little scientific training. The time which they devote to their subjects in the Universities is insufficient to allow them to receive any other type of education save that of assimilating as much knowledge as possible, chiefly by memory work. In dealing with this problem—Scientific Education in India—I propose, therefore, first of all to deal with the problem of Scientific Education in the Middle and High Schools.

Scientific Education in Schools

The history of Scientific Education in Schools in India is very largely a record of unfulfilled hopes. Because of the fact that education has for many years now been almost entirely a Provincial responsibility, the facilities provided in schools differ, and differ enormously, in the various provinces. Some of the provinces have for many years been aware of the necessity for making provision for scientific education in all types of schools. On paper much has been done. In practice, with one or two notable exceptions, very little has been achieved.

In the *United Provinces*, Elementary Science, in some form or other, has been taught in schools for a period of nearly 40 years. As far back as 1910 not only theoretical science but practical classes also found a place in the curriculum. Middle Schools had

classes for nature study, as well as elementary science, while even in the Primary Schools certain simple observational lessons were given. Unfortunately the provision of these facilities, because of the fact that the subjects were optional ones, did not lead to a wide extension of scientific teaching to many students. When, in 1922, a Board of Intermediate Education was formed in accordance with the recommendation of the Simon Commission on Reforms, while Science teaching was left as a theoretical subject, the practical examinations were abolished. The reason given was lack of funds. At the present moment in that province theoretical science courses exist, and as soon as funds are available practical examinations will be restarted. A general science course as distinct from the Physics, Chemistry and other special subject courses has been introduced. No schools are recognized for science teaching unless there is laboratory provision for practical work as well as class-room arrangements for theoretical teaching. That a certain measure of success has attended the effort of introducing science teaching, is evidenced by the fact that of the candidates taking the final school examination, equivalent to Matriculation, no less than 25% take a science subject.

In *Bombay*, prior to 1913, Nature Study—Mechanics, Astronomy and Chemistry were taught in schools as purely theoretical subjects. In that year practical work was introduced. Even now, however, while provision is made in certain schools for the teaching of Physics, Chemistry, Physiology and Hygiene throughout the School course, from Class I to Class VII, these subjects are not examination subjects, with the inevitable result that satisfactory progress has not been made. In 1925 the taking of one science subject was made compulsory in the Matriculation.

The story is somewhat similar in other provinces. The most progressive appears to be the *Punjab* where, not content with following somewhat slavishly the system that has been found successful in Western countries, the authorities have set out to solve the problem of adjusting the scientific education given in schools to the needs of the ordinary rural student whose life must in all probability be spent in rural surroundings. In the Punjab, Middle Schools have a far more important place in the educational scheme than is usually the case in India, and it is not surprising to find that as these schools have for many years been developed as institutions meeting very largely the needs of the village boys and girls, the science teaching has been designed as a rural science, and the syllabus has been adopted to create interest in, and give knowledge about such points of the pure sciences as affect the agricultural practices. In High School Education, science teaching is still an optional subject for Matriculation and it has not been assimilated to a very marked extent in the ordinary school activities.

Bengal is far behind the other provinces. So far the Matriculation Examination has, in practice, not included any scientific sub-

jects. The only education that can in any sense be called scientific is that which has been given in the very few schools which have adopted as an alternative to Matriculation what is known as the 'B' Course. This Course is a specially devised one, leading in general to admission to an Engineering School or College. It includes certain teaching in Mechanics and Physics, but the work is of an elementary nature and far from satisfactorily carried out. To all intents and purposes it has no appreciable effect upon the general work of the few schools in which it is carried out. There is no Science teaching worth the name in any of the ordinary Bengal High Schools.

The result is that when students enter the University and start on a science course, they have to begin with the most elementary portions of their subject. There is no time for any teaching of scientific principles and the whole University course is a race against time in order to go through the syllabus which on paper is not far different from that followed in the West. Contrast this state of affairs with that which exists in other lands. As a rule a student who is to undertake a science course at the University receives scientific education including, in addition to his special subjects, general observational lessons and general science teaching. This scientific education begins at an early age and gradually more importance is attached to the subjects in which the student is to specialize. He receives both theoretical and practical training in at least two, sometimes three science subjects. In addition, he is generally conversant with matters of scientific interest because of the contacts with various scientific problems in his home and leisure time. He is taught by a man, generally specially trained, whose idea is first and last to make his pupil understand the subject as well as to get through an examination. By the time he enters the University he has not only assimilated a valuable knowledge of principles and facts but also—unless he has been extremely unlucky—has acquired a reasonably thorough understanding of the principles and laws operating in the physical world. Such preliminary training is entirely absent in Bengal and in most of the other provinces. Even where facilities have been provided there have been two factors at work which have prevented any real development of satisfactory teaching or wide-spread expansion of facilities. The first of these is that until quite recently few Indian examinations included as compulsory any science subject. The second is the inability of the authorities to provide the funds required for the necessary equipment. The first of these, namely the fact that science has been an optional subject within the curriculum would be an important factor in any country.

In India, where Examinations are worse tyrants than elsewhere, they have been fatal to progress. As all educational institutions have in general unsatisfactorily prepared material upon which to work, their energies and activities are necessarily very largely

concentrated upon doing the necessary and compulsory work in connection with these examinations. Fortunately there are signs that this condition of affairs is changing.

In the *United Provinces* it is compulsory now for all Matriculation candidates to take one science subject. In *Bengal*, in the future, science teaching will be compulsory in all the high schools and one elementary paper will have to be taken in the Matriculation. Whether this will be effective in creating a deeper interest in scientific studies, and, more important still, of giving a better foundation upon which the Universities can build more satisfactorily than has so far been possible, is a matter about which one may justifiably have doubts. It is easy by a resolution to decide that a changed condition of affairs shall come into existence. It is a very different matter to ensure that the changed condition of affairs will be the desired one, when ensuring such changes means finding more money, and providing equipment and facilities. In Bengal, for example, the majority of the schools live from hand to mouth. Their finances are in a deplorable condition. Teachers are ill-paid, there are no reserve funds to meet emergencies and there is little possibility of providing reasonable facilities for effective teaching. From where are these schools to get the funds to build and equip a laboratory and pay trained science teachers ? There is a danger that the introduction of this course in elementary general science will, in practice, develop into a sterile knowledge of useless facts contained in certain books. That is not scientific education. In order to avoid failure two things are necessary. A wide appreciation of the danger, and the provision from some source or other of more funds. The condition of affairs in Bengal is, I believe, worse than that in other provinces chiefly because of the fact that the financial conditions of the schools here are worse than elsewhere. Nevertheless this problem of finance has to be faced by every province. Without exception the authorities in the different provinces have stated that the greatest obstacle to progress is lack of funds. Additional financial resources must be made available. It is of no use deluding oneself with the idea that effective scientific education can be introduced satisfactorily without additional expenses being incurred. It is not necessary of course to build palatial laboratories and import expensive foreign made apparatus, but it is essential to have some kind of laboratory and to have some apparatus. It is unfortunately a fact, therefore, that this question of satisfactory scientific education in the schools is largely a financial problem. It is one of the problems that will have to be solved. It is not impossible of solution, as it has been solved in other lands. It probably means concentrating upon larger and well-equipped high schools rather than relying upon a greater number of ill-equipped institutions more widely distributed. That is a controversial subject into which I do not wish to digress here.

What must be emphasized is that unless India desires to recede further and further in the race for efficient scientific education, it will have to face the problem of satisfactory provision of facilities in its Middle and High Schools.

Curriculum of Scientific Studies

Another extremely important problem concerned with school scientific education is that of the nature of such education. Not many years ago scientific education meant a fundamental knowledge of Mechanics, Physics, Chemistry and occasionally also Botany. There has been a rapid and widespread change in the conception of desirable scientific teaching. In the West not only are the elements of Physics and Chemistry now taught but Botany, Biology, Physiology, Zoology, etc. find their places. They are not taught as separate special subjects and the knowledge given is general rather than specialized. The idea that is being increasingly adopted is to interpret all teaching in terms of actual experience and conditions of life. Consequently the problems which a boy naturally meets in his ordinary life and his natural curiosity about phenomena that come within his observation now come within the scope of his school education. They form the natural starting point for a child's scientific education. It is true of course that it is desirable and necessary to deal with the few scientific principles that find expression in various natural phenomena, but more and more the somewhat dry text-book teaching of the ordinary examination syllabus of Physics and Chemistry commonly found 20 years ago is giving way to schemes which attempt to make scientific teaching an expression and understanding of natural experiences in life. As a result, general science courses are given as compulsory teaching to all students and more detailed teaching in special subjects is given, in addition, to those students who desire a more comprehensive scientific training as preliminary either to University studies or a technical application of their scientific knowledge to industry. It is both a natural and desirable development. It is an acknowledgment that education must deal with life's problems rather than be a mere intellectual exercise with an abstract and departed culture. This trend is wisely being followed in India, but we have a great distance to go before we see in our schools conditions which make this ideal attainable. Eventually, we must firstly have an elementary scientific training and knowledge given to all students, and secondly sound fundamental teaching in specialized branches. One point should be emphasized. It is that such teaching demands a better and more highly trained teacher than does the old type of teaching. General science or special science if taught by a person who either does not understand his subject or, if he does, is incapable of transmitting that understanding to others, so far from being a valuable asset in school training would be a definitely undesirable development.

Training of Science Teachers

So far the question of the training of science teachers for work in Secondary Schools has not been taken particularly seriously. There are signs that the necessity for it is realized. In *Bengal* short-term training courses for science teachers are at the present moment being held, and it is intended to hold them more frequently in the future. With the introduction of compulsory science teaching in schools it is probable that the emphasis which is laid on the training of science teachers in the ordinary training college courses will be increased. In the *United Provinces* the training colleges already give specialized courses of training for science teachers. In *Bihar* provision is made for a special training in the training colleges for those teachers who wish to teach science. In the *Punjab* special courses in science teaching are included in the Training College at Lahore. So also in the other provinces. There are thus signs that the individual authorities are aware of the urgency of the problem, and it is hoped that there may soon exist in India a reasonably large body of well-qualified science teachers whose work in the schools will begin to have an appreciable effect upon the scientific training given to the boys. My own experience is, however, that the ordinary science graduate has such an insecure foundation of scientific knowledge upon which to build that it is difficult, if not impossible, to make him an efficient teacher of young boys and girls. He himself has usually never been taught the subject as a science and, of course, in the very short time at the disposal of the training authorities it is not possible to deal with anything save the methods of teaching. A re-teaching of the subject matter to the student teacher is impossible. Thus while much have been done theoretically in the past in attempting to introduce science teaching into our schools, the progress achieved has not been satisfactory. The conditions to be fulfilled before there can, in the future, be any real progress involves such radical changes of the present condition of affairs that any rapid growth towards a better state of things is improbable. It is possible that, as practically the whole of my personal experience has been in one of the provinces where admittedly least has been done, I hold an unduly pessimistic view of the future. A perusal of the reports that have been sent to me from the other provinces, while they indicate that there are isolated examples of real achievement, reveal in general a depressing condition of affairs. In *Burma* since 1920, in both Vernacular and English High Schools, the teaching of Physics and Chemistry has been included in the curriculum. Since 1932 general science has been included in the Vernacular Schools curriculum. Teaching is optional at present. In only 10 schools has the teaching of Physics and Chemistry been introduced, while general science has been introduced in certain schools. Eleven Vernacular schools teach science, but a recent survey reveals the fact that no such school has any equipment worth the name. The enquiry revealed

that in the Vernacular schools the teaching merely consisted o: text-book exercises. Certain provinces formerly had Inspectors of science teaching. Their work was reported to be good and stimulating. Now I believe that in all such provinces as a matter of retrenchment these posts have been abolished. While the Inspectors were there, they managed to keep up a reasonable standard of teaching in the schools they visited. Since their abolition the general report is that it will not be possible to maintain the advance in scientific education that might otherwise have resulted. Everywhere, therefore, the position seems to be that while the authorities are beginning to recognize the educational as well as the scientific value of providing better facilities for science teaching than are available at present, there are no signs that the necessary money for implementing that desire will be forthcoming, nor is it certain that if the money is available there will be the necessary inclination and determination to see that it is not alienated in other directions.

Committee of I.S.C. for suggesting Science Curricula for Schools

One useful function that the Indian Science Congress Association might perform is that of devising for schools in India a suitable course of instruction in scientific subjects. It would, I think, be a useful action if the Education Section[1] were to appoint a committee consisting of at least one expert in each of the leading branches of science together with 3 or 4 of its trained educationists to study the schemes that have been brought into existence in the various provinces and to lay down certain principles which would be of help to the different authorities when they are developing their plans in the future. It would, I think, for example, be wise if the Punjab schemes for rural Middle Schools or schemes devised upon the same lines were adopted throughout the country, and if desirable schemes for town M.E. Schools and High Schools were also devised. The report from such a Committee could with advantage be in two parts, one dealing with the general scientific education which it is desirable for every student to undertake, and the other dealing with the more detailed scientific education necessary for those students who desire to specialize.

Scientific Training in Schools

I have so far stressed mainly the desirability of reasonable scientific education in our schools from the point of view of education itself. Another aspect, which is also of very great importance, is that until the students entering the Universities have had a far more thorough and satisfactory foundation training in the scientific principles and in the elementary branches of the individual subjects it will be impossible for the Universities to achieve reasonably good results and provide teaching that is really of the University standard. The Universities have in the past done their best in what has been an almost hopeless task. In this task they have achieved results which, considering all the circumstances, are

[1] At present there is no separate Education Section of the Indian Science Congress.—(*Editor.*)

remarkable. It is a tribute to the mental powers of many University students that they have been able, with such unsatisfactory preliminary training, to achieve such high standards of knowledge and have been able to rank themselves with the leading students of the world. As all who have dealt with University students know, however, that such students are in the minority and the average undergraduate, ill-prepared during his school days for a scientific training, is so handicapped, that it is impossible satisfactorily to train him in scientific principles. It is these average graduates who determine the standards attained and the syllabus of studies pursued.

Age Limit

Many students in Germany and other Western countries are better scientists when they enter a University than many of the graduates here when they This is the result of different scientific teaching over a period of many years in well-equipped schools. There is one other factor that leads to unsatisfactory work within our Universities and that is a factor that affects all University teaching. The age of admission to the Universities is gradually decreasing. The Matriculation or equivalent examinations are such that able students can pass them at the age of 15, or even earlier. This is so also in England, but whereas in India students seldom, if ever, stay on at school after taking the Matriculation it is not uncommon in England for students to remain on at school for a period of two years beyond that Examination. Universities in England will not, as a rule, admit students until they are approaching their eighteenth year. It is otherwise in India, with the inevitable result, that as quite apart from the question of efficiency of school teaching—the actual time during which a student is being prepared for a mature University course is nearly two years longer, even for the ablest students, in the West than it is here. Under such circumstances, University work here must of necessity be far less satisfactory than might otherwise be the case. This problem of allowing students to embark upon a University course at an unduly early age is far more important than would be inferred by the alacrity with which Universities have in general removed restrictions as to age admission. The age limits in examinations held for admission to the Public Services are partially responsible for this. Those responsible for University standards and University prestige might do worse than investigate this problem to see if it is not possible to restore the conditions which make Universities training organizations for more mature minds than is often the case at present in India.

II. College Education.

The quantitative expansion of scientific education within the various colleges in India has been remarkable. A quarter of a century ago few facilities existed and science students were a rarity

in all Universities. In Bombay, for example, in the year 1910 fifteen students only succeeded in passing the B.Sc. Examination. The number 20 years later was 363. This is typical of the progress in other provinces. Unfortunately it cannot be said that there has been a correspondingly rapid improvement in the quality of the work done in the ordinary B.Sc. Examinations. The ordinary students are handicapped by the inadequacy of their pre-University preparation. In addition the rapid increase in numbers of students necessitating something very much akin to mass teaching inevitably meant that little improvement in the standards attained could be ensured. The ordinary science graduate is still not satisfactorily prepared either for any practical application of his scientific knowledge or for an immediate proceeding to research in his subject. Fortunately the institution of Honours courses has resulted in the provision of more adequate facilities and satisfactory teaching for the better students. Here again, however, in certain Universities lack of funds has precluded the provision of really satisfactory facilities, even for these students. When Honours courses were first started in the older Universities in India, students who took these courses were required to attend the same lectures as Pass students. They had, in addition, to attend advanced lectures in various branches of their subjects. As the time table of the ordinary Pass students was inevitably a crowded one, leaving little leisure for additional work, the result was that the standard attainable by Honours students was very much lower than it might otherwise have been. When the newer Universities were formed, the handicap inherent in such an arrangement was recognized, and in certain Universities, for example Dacca and Allahabad, Honours teaching was entirely separated from Pass teaching. Moreover the Honours course was made a three years course instead of the normal two years, post-Intermediate one, required from Pass students. As far as work was concerned this system has proved an undeniable success. On the average, Honours students are of a higher mental calibre than Pass students and the fact that they are taught in their special subjects in small classes for a continuous period of 3 years means that rapid progress to an advanced stage is possible. As a compensation for being required to spend 3 years in obtaining their Honours Degree such students are allowed to take their M.Sc. Degree after one year's further study. Thus whether a student takes a Pass Degree or an Honours Degree the post-Intermediate study required before taking the M.Sc. Degree is the same.

Progress of Scientific Education

From the academic point of view there is everything to be said for the specialized three years Honours Course. It has not been followed in all the Universities, in spite of the recognition of its merits, because of the fact that there are considerable advantages attend-

Three years Honours Course

ant upon the acquisition of a Degree of any kind at as early a date as possible. It is apprehended by those who have not adopted the new scheme, not without reason, that if the Honours Courses were transformed into 3 year ones many students, who now take up Honours would prefer to take a Pass Degree in order that they might graduate one year earlier than is possible when taking an Honours Degree. Because of this there has not been any universal acceptance of the 3 year Honours scheme throughout the Universities, and because of this fact, at the present moment Honours teaching and standards differ enormously in the different Universities. Attempts have been made to obtain uniformity but without success, and it appears that until there is no difference between the length of time required for an ordinary Degree and Honours Degree, there is little chance of abolishing this anomalous position with regard to Honours teaching. The present position is, therefore, that an Honours Degree in certain Universities connotes an entirely different standard from that of an Honours Degree in other Universities, and it is to be feared that unless some agreement can be reached which will enable the Universities to establish the specialized 3 years Honours Course, the newer Universities which have done admirable work and set very high standards in their Honours teaching may feel themselves compelled to abandon what has undoubtedly been a valuable contribution to educational progress in this country.

Three Years Pass Degree

One solution that has been proposed is that the Pass Degree also should be made a three year one, but I do not feel that public opinion will permit of this under the present economic conditions. The University Course is already a 4 year one as against 3 years in most foreign Universities and any attempt further to lengthen it would raise almost irresistible opposition. A better solution would appear to be that of attaching to an Honours Degree a status and privileges which will adequately recompense the student who is prepared to specialize for a period of 3 years in one particular subject in addition to taking the ordinary Degree subjects in the normal 2 years. The reason why the early obtaining of any kind of Degree is of value is that for most Public Service Examinations and admissions to most professions, the qualification laid down for entrants is that of possessing any kind of Degree. If the Public Service Commission were to require an Honours Degree as a necessary qualification for candidates taking their examinations, and the Provincial Governments were to follow the lead given by the Federal Public Service Commission there would not, I think, be much reluctance on the part of students to enter for a 3 years Honours Course. The replacement of the present 2 years Honours Course in the older Universities by a 3 year one would also probably have the effect of limiting Honours teaching to those Colleges which were in a position to provide satisfactory teaching and satisfactory laboratory

facilities. This again would rouse a certain amount of opposition, but would eventually prove a valuable reform. Such reforms to be practicable must be accepted generally by all the Universities.

Unfortunately, although there is an annual meeting of the representatives of various Universities at the Inter-University gathering, the individual Universities are, in practice, independent units which pay little heed to the general recommendations made to them by other bodies. Whether it is that they are jealous of their autonomy or unable, for financial reasons, to carry out the recommendations which are made, is immaterial, but it is a fact that few, if any, of the general recommendations which have been made from time to time by the Inter-University Board have had any influence upon individual University developments. This problem of the specialized Honours Course is one about which such a Board could with advantage give an authoritative opinion and make a strong recommendation to the Universities. It is one of the points about which there should be reasonable unanimity of opinion and uniformity of policy.

As might be expected a greater part of the work which has been done in scientific education in the Colleges has been in connection with the old established and perhaps scientifically fundamental subjects such as Physics and Chemistry. Until recently there were few science students in subjects other than these save perhaps Botany. The latter subject has become extremely popular and in certain Universities has the reputation of being an easy option.

Standards in different Universities

One point to which adequate attention has not so far been paid is that of the differing standards attained in different subjects in the ordinary and Honours Examinations. In one University, for example, it is possible and not unknown for a student to take up Botany in his final examination without having read that subject either at school or in his Intermediate Course and to obtain an Honours Degree after 2 years' study. The same applies to other subjects. It should be obvious that the standard of work connoted by an Honours Degree which requires merely 2 years' total study must be entirely different from that which is connoted by an Honours Degree in a subject which has required 4 years' University study and sometimes several years of school work in addition. Sufficient attention has not been paid also to the correlation of subjects taken by individuals presenting themselves for Degrees in certain Universities. For example, it is possible for a student while taking an Arts Degree to read Chemistry or some other science subject. The fact that a satisfactory knowledge in Chemistry cannot be obtained without a knowledge of Physics and Mathematics or that a satisfactory knowledge of Botany is not possible without an elementary knowledge of Chemistry, does not seem to have been realized. In the newer Universities science

subjects can, as a rule, only be taken by students taking a complete science course, and in one University at any rate the science course is a uniform one. This makes possible correlated scientific education, creating an attitude of mind as well as giving a knowledge of scientific facts. No Indian University has, so far as I know, followed the example of at least one foreign University in making Physics compulsory at the Intermediate stage for all science students. The principle behind this is sound and is one to which greater attention might with advantage be paid in India.

Post-Graduate Studies

Of recent years there has been a wide extension of scientific education for ordinary students into such subjects as Physiology, Geology and Zoology. Provided the students have had a reasonably sound foundation learning in elementary Physics and Chemistry this is an admirable development, and the provision of specialized courses in the more advanced scientific stages in such subjects as Bio-Chemistry, Agricultural Science and the technical applications of the pure sciences is a very desirable trend of modern developments. During the last 15 years there has been a phenomenal growth in the facilities which are provided for advanced students for research work in different branches of science. The admirable scheme devised and put into practice by Sir Asutosh Mookerjee has given an impetus to Post-Graduate studies not only his own University but also to the other Universities in India. The volume of research work which is now being done is remarkable considering the unsatisfactory nature of school and college education and the financial resources of different educational institutions. One of the facts which makes this possible is the unfortunate fact that so few worth while openings exist for employment after graduation. This added to the fact that students can and do live in a frugal and economic manner upon allowances which would be quite inadequate in other countries, has made possible a devotion to research which is one of the noticeable features about University work in some of the Universities in India. In Calcutta, for example, there are Post-Graduate departments in almost every branch of studies with adequate facilities for research in whichever directions students may wish to work. This has been made possible in the pure sciences by the very generous endowments which have been given to the University, making possible well-equipped laboratories and the appointing of well-qualified staffs. These endowments also provide opportunities for a large number of able students to proceed abroad for further training.

Another fact which has given an impetus to research work is the world-wide recognition which has been won by a number of Indian Scientists and the reputation which through them has come indicating India's capacity to provide people of a high order of intelligence. It is quite certain that their achievements have contributed not a little to the prestige of India throughout the

world. The inspiration of their names and their work has led many students, desirous of following in their foot-steps, to turn to research work as an ideal. This desire for research has, however, raised up problems not easy to solve. Undoubtedly a great deal of the research work which is at present being done is more in the nature of routine advance experiments than creative discovery making possible new developments. Personally I am inclined to think that many students now engaged upon research would be wise to devote a longer period to their preparation for research. Wide-spread facilities are offered in all Universities for the taking of the M.Sc., and in some cases even the Honours Degrees, in part by means of theses professedly embodying research activities. It is, I think, a justifiable criticism of many of these theses that they embody work of no real research value. They deal with problems which could have been more profitably undertaken at a later stage when the student had obtained a sounder knowledge of the fundamentals of his own and other sciences. Before a student should attempt to carry out experiments or interpret knowledge in such a manner that it can rightly be described as research work, it is essential that he should possess a sound knowledge of all scientific principles a knowledge of which is necessary for a real scientific understanding of any subject.

Occasionally, very occasionally, there appear students who obtain a grasp of their subject at an early stage and for these it would not be wise to insist upon the acquisition of book knowledge beyond a certain stage. These students are undoubtedly exceptions, but I feel convinced that to allow a large number of students to present theses for the M.A. and M.Sc. degrees is denying them the opportunity of acquiring that sound fundamental scientific training which makes possible at a later stage real contributions towards scientific knowledge. It is significant that in certain subjects this allowing of the presentation of theses for ordinary examinations has been discontinued. It is, I think, a privilege that should wisely and severely be restricted in all subjects.

Naturally, as far as research work is concerned, extensive facilities are limited to the larger Colleges and towns. In every province, however, there is very considerable activity, and there are signs that the value of the work which is being done is being recognized even by commercial firms. Recently in the Punjab one firm has placed a sum of money at the disposal of the University through a leading Professor. A recognition of the merit of his work was the origin of this gift. This is an example which might well be followed in other parts of India, with advantage both to the commercial firms and to the Universities.

Retrospect

Looking back on the period one sees that much has been done but that much remains to be done. Progress has, in the main, been the result of individual achievement and greatness. That progress has provided for Indian

students inspiration and has brought reasonably widespread facilities, not only for normal scientific education in ordinary and Honours Degree courses, but opportunities for research work and practical training. It is now possible for students to develop their innate powers and by extending the bounds of knowledge to bring recognition to themselves and to their country.

Future Problems

So far the research which has brought the greatest recognition to this country has been research in the physical sciences. With the extension of scientific teaching to other subjects it is to be hoped that research facilities in other directions will spread as rapidly as have the research facilities in Physics and Chemistry. There are more virgin and wider fields in subjects like Botany, Geology, Physiology and Bio-Chemistry than in the more frequently trodden grounds of Physics and Chemistry. Moreover, in many of these branches well-equipped and expensive laboratories such as are available only in the large Colleges and towns are not essential for the production of valuable work. These are directions in which men of genius in small colleges and residing in the rural areas should find an opportunity for explorations of value during their leisure time and in their immediate surroundings. Research work encounters many difficulties in this land which are absent in others. At the present moment it is only men of undoubted genius who are able to triumph over the difficulties which are encountered. The greatest inherent difficulty is the lack of a sound fundamental education. It is the business of educational authorities to minimise these difficulties and to provide satisfactory accommodation and facilities and efficient teaching. It is the business of the commercial and industrial firms, which stand to gain by the results of research work, to make possible the building and equipping of laboratories and the carrying out of work upon problems, the solution of which is to their advantage. Considering the difficulties, scientific education in this country has made astounding progress. Its progress will be still more rapid and effective when the following problems have been solved :—

1. The reorganization of Secondary School systems so as to guarantee a sound fundamental education and preliminary scientific training. This means the guaranteeing of a satisfactory elementary scientific training for all students, and, in addition, the provision of more specialized and detailed scientific training for students who wish to become scientists in the real sense of the term.
2. The reorganization of University studies so as to guarantee a sound knowledge of all the fundamental sciences which will serve as a foundation upon which to build satisfactorily for advanced scientific study and research in any branch.

3. Obtaining the co-operation of industrial and commercial firms in schemes for research activities in various directions.
4. Obtaining endowments for research in the pure sciences which have no direct, immediate commercial applications.

PROGRESS OF MATHEMATICAL RESEARCH IN INDIA DURING THE PAST TWENTY-FIVE YEARS.

By

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CONTENTS

I. INTRODUCTION.

India can claim a prominent place in the mathematical world as the country which gave to the world the system of representing all numbers by means of ten digits—the system which forms the foundation of all Mathematics. Her contribution to the early development of Astronomy is also noteworthy and several astronomical observatories (crude as they may appear compared with the modern ones fitted with precision instruments) built centuries ago in different parts of Northern India bear testimony to the zeal and thoroughness with which the study and research in Astronomy were pursued.

The study and research in Mathematics and other scientific subjects on modern lines began in India rather late, and the beginnings may perhaps be identified with the foundation of the Asiatic Society of Bengal about a century ago. For many years the contributions consisted of papers written by Europeans on various scientific subjects, specially Geology and Meteorology, and published in the Journals of the Society. Gradually, however, Indians began to interest themselves in scientific work and the record of progress that they have made during the last quarter of a century is very remarkable.

The lead in the field of mathematical research was given by the late Sir Ashutosh Mookerjee, the President of the first session of the Indian Science Congress, who began his career as the pioneer mathematical researcher, but later on took to the profession of Law, rose to be the Chief Justice of the Calcutta High Court and distinguished himself as the foremost educational reformer of India. Fifty years ago, he published several papers on Differential Equations in the *Journal* of the Asiatic Society of Bengal; these were later incorporated in the works of Edwards and Forsyth. One of the most remarkable results he arrived at was that the left hand side of Monge's differential equation to all conics, which had been described by Boole as incapable of geometrical interpretation and merely an integrable form, was geometrically interpreted as the radius of curvature of the curve of aberrancy. Sir Ashutosh wrote about sixteen original papers in Mathematics during the three to four years that intervened between his graduation and the beginning of his career as a lawyer.

Sir Ashutosh Mookerjee

Among the pioneers of mathematical research in India, the name of the late Dr. Ganesh Prasad, Hardinge Professor of Mathematics in the Calcutta University, deserves special reference. He published his first paper ' On the potentials of ellipsoids of variable densities ' as early as 1900 (*Messenger of Mathematics*, **30**). He was the author of a fairly large number of notes, papers and memoirs. His work can roughly be classified in three groups. The first group consists of papers on Applied Mathematics, specially in the theory of potentials, in which he employed his knowledge of the theory of functions of a real variable. The writers previous to him had not considered the cases in which, under special circumstances, the differential coefficients either became infinite or did not exist. Dr. Prasad made a thorough investigation of such cases. An important contribution to this group was the memoir entitled ' Constitution of Matter and Analytical Theories of Heat ' (*Gött. Abh.*, **2**, 1903). The second group consists of papers on the theory of functions of a real variable, mainly on Fourier Series. This constituted the bulk of his work. He has given a number of results concerning the summability and strong summability of Fourier Series. He based most of his work on a special type of functions having discontinuities of the second kind. The function $f(t) = \chi(t) \cos \psi(t)$, in which $\chi(t)$ is limited or unlimited but monotone and $\psi(t)$ is monotone in the neighbourhood of the origin and tends to infinity as t tends to 0, served throughout as an unfailing weapon in his investigations. His third group of papers consists of those on spherical harmonics, chiefly on Legendre's function and series. He has given an interesting theorem by means of which an arbitrary function can easily be expressed as a sum of surface harmonics (*vide* Hobson, *Theory of Spherical and Ellipsoidal Harmonics*, p. 148). Here, too, he

Dr. Ganesh Prasad

employed his favourite function $f(t)$. He had planned an elaborate memoir on the 'Expansion of Zero', but he died before he could finish it.

S. Ramanujan

The most distinguished mathematician that India has ever produced in modern times was S. Ramanujan, who, without any university education, began researches in Mathematics more as a hobby than as a profession. While a clerk in the Madras Port Trust, his remarkable mathematical abilities attracted the attention of the authorities of the Madras University and specially through the personal interest of Prof. Hardy (who had come to know Ramanujan by correspondence), he secured a Government Scholarship, which enabled him to proceed to Cambridge and continue his researches under the guidance of Prof. Hardy. Most of his work was concerned with the Theory of Numbers. He was elected a Fellow of the Royal Society in 1918 and was the first Indian mathematician to get the high honour. In the words of Prof. Hardy, 'he is beyond question the best Indian mathematician of modern times .... He will always be rather eccentric in his choice of subjects and methods of dealing with them ..... But of his extraordinary gifts there can be no question; in some ways he is the most remarkable mathematician I have even known'. Unfortunately for India and the world, this mathematical genius passed away at the very young age of thirty-three, only two years after his election as a Fellow of the Royal Society. A full account of his life and work is contained in 'Collected Papers of Srinivasa Ramanujan' edited by G. H. Hardy, P. V. Seshu Aiyer and B. M. Wilson, and published by the University Press, Cambridge.

It is not possible to give in the short space at our disposal anything like an adequate account of what has been done in India during the last thirty or forty years in the field of mathematics, and in this chapter only a brief outline is given of the work that has been done in the various subjects, without strict reference to their chronological order.

II. Geometry.

A most remarkable contribution to Geometry was made by the late Dr. S. Mukhopadhyaya, who was a Professor of Mathematics in the University of Calcutta. He was the first to prove the theorems (later re-discovered in Europe) that every oval possesses at least 4 cyclic and 6 sextactic points. He afterwards generalized these results, proving that if a circle (conic) meet an oval in $2n$ points then the oval has $2n$ cyclic (sextactic) points. The connection between cyclic points and normals has also been studied by him. P. Ganapati has shewn that all the cyclic points of an oval cannot lie on a circle. R. C. Bose has shewn that the sextactic points cannot all lie on a conic. Ovals for which derivatives of higher

order than the first are non-existent have been considered by S. Mukhopadhyaya in two of his papers. The properties of convex ovals and ovaloids in relation to the various kinds of centroids, have been studied by R. C. Bose and S. N. Roy, specially the locii of these centroids for a system of parallel ovals or ovaloids. [Vide *Bull. Cal. Math. Soc.*, **1** ; *Math. Zeit.*, **33** ; *Bull. Cal. Math. Soc.*, **10** ; *Math. Zeit.*, **35** ; *J. Ind. Math. Soc.*, **2** (New Series) ; *Math. Zeit.*, **30** ; *Tohuku Math. J.*, **34** ; *Bull. Cal. Math. Soc.*, **27** ; etc.].

Corresponding to the Gaussian pentagram of elliptic geometry, there are known to exist 5 right-angled triangles and 5 tri-rectangular quadrilaterals of the hyperbolic plane. S. Mukhopadhyaya completed this system by showing the existence of a five-right-angled hyperbolic plane pentagon associated to the other 11 figures and thus gave an objective basis for Engel-Napier rules (*Bull. Cal. Math. Soc.*, **13**). R. C. Bose has shown that this system of associated figures is a degenerate case of a system of 12 associated skew rectangular pentagons of hyperbolic space (*Bull. Cal. Math. Soc.*, **28**). He has also extended the theory of associated figures to general triangles (*Bull. Cal. Math. Soc.*, **19** and **28**) and also to certain types of polyhedra (*Ind. Phys.-Math. J.*, **3**). S. Mukhopadhyaya and G. Bhar have made very interesting generalizations of the concurrency theorems for the hyperbolic triangle (*Bull. Cal. Math. Soc.*, **12**).

A. Narasinga Rao investigated mainly specific geometrical topics, particularly the geometry of quadric manifolds and geometrical transformations. In one paper, he discusses, in general terms, the conditions under which the derived locus splits up into the maximum number of algebraically distinct components. It is shewn that such utter degeneracy is connected with the theory of the polyhedral groups. In another paper he classifies the quadrics of revolution through a given conic by associating each with its axis of revolution (*J. Ind. Math. Soc.*, **15**). He has also studied the complex curves on a quadric surface (*Atti del Congresso Internazionale dei Matematici Bolagna*, **6**), the axial involution of a net of conics and its associated (1, 2) Connexes (*J. Ind. Math. Soc.*, **18**) and certain transformations in circle space connected with the theory of the Miquel-Clifford configuration (*Proc. Camb. Phil. Soc.*, 1937). He has also published a number of other papers on allied topics.

A number of papers relating to tetrahedra have been contributed by N. D. Rajan (*J. Ind. Math. Soc.*, **5**), Hemraj (*J. Ind. Math. Soc.*, **15**) and Kasikar (*Math. Student*, **2**). A number of papers relating to conicoids have been written by R. Vaidyanathswamy [*J. Ind. Math. Soc.*, **19, 2** (New Series)], V. Ramaswami Ayer (*Math. Student*, **2**), A. A. Krishnaswami Ayer (*Math. Student*, **3**), S. Mukhopadhyaya (*J. Ind. Math. Soc.*, **19**), K. K. Mitra (*Bull. Cal. Math. Soc.*, **24**), C. N. Srinivasienger (*Bull. Cal. Math. Soc.*, **27**) and B. Ramamurti (*Math. Student*, **4**). A number of papers on ruled

surfaces have been written by R. Vaidyanathswamy (*J. Ind. Math. Soc.*, 8), R. Behari [*J. Ind. Math. Soc.*, **19**, **20**, **1** (New Series), **2**, *Ind. Phys.-Math. J.*, 7], C. N. Srinivasienger [*J. Ind. Math. Soc.*, **18**, **19**, **1** (New Series)]. Certain special types of surfaces have been investigated by R. Vaidyanathswami (*J. Ind. Math. Soc.*, **9**), A. Krishnaswami Ayienger (*J. Ind. Math. Soc.*, **19**) and V. Rangacharier [*Bull. Cal. Math. Soc.*, **23**; *J. Ind. Math. Soc.*, **19**, *Bull. Cal. Math. Soc.*, **27**, *J. Ind. Math. Soc.*, **1** (New Series)].

B. M. Sen has investigated the classification of double surfaces under certain restrictions. Unifacial or double surfaces fall into three classes. All algebraic double surfaces have at least one double line. Cubic and quartic double surfaces are determined. It is shewn that one of the centro-surfaces must also be a double surface. Bonnet's associates of double minimal surfaces are deforms, but are not one-sided. This anomaly has also been explained (*Proc. Lond. Math. Soc.*, **20**). B. M. Sen has also discussed the distinction between the applicability and deformation of a surface and its bearing on the general theory of deformation (*Proc. Camb. Phil. Soc.*, **22**). H. N. Datta has written a paper on the use of Riccati's equation in the theory of geodesics (*Proc. Benares Math. Soc.*, **3**).

Balak Ram has given a new proof of the theorem that when a flexible extensible surface is deformed, the Gaussian curvature remains constant (*J. Ind. Math. Soc.*, **2**). B. M. Sen has shewn that the partial differential equation of the Monge-Ampere type, on which the deformation of surfaces is supposed to depend, is a necessary but not sufficient condition (*Bull. Cal. Math. Soc.*, **10**). C. N. Srinivasienger has investigated the methods of determination of one-parameter and two-parameter systems (*Tohuku Math. J.*, **39**). A number of papers on ovals and ovaloids have been contributed by P. Ganapati (*J. Ind. Math. Soc.*, **19**). He has discussed the properties of the ovals called ' Su Oval ' which satisfies the equations

$$\rho \cos 2\phi d\phi = \int^{2\pi} \rho \sin 2\phi d\phi = 0,$$

where ρ is the radius of curvature at a point of the oval and ϕ is the angle between the corresponding tangent plane and a fixed plane (*Math. Zeit.*, **38**). M. M. Ghosh has written a few papers in plane geometry (*Bull. Cal. Math. Soc.*, **13**, **19** and *J. Department of Science, Cal. Univ.*, **10**). P. N. Das Gupta has worked in algebraic geometry, dealing particularly with Invariants and Covariants of two linear complexes (*Proc. Lond. Math. Soc.*, **31**). He has also a few papers in the same line in collaboration with Prof. H. W. Turnbull and with N. Chatterji. R. Behari has contributed a

series of papers on the differential geometry of ruled surfaces and has established a number of interesting general properties. His papers have appeared in several Indian Journals (*J. Ind. Math. Soc.*, **19**, **20**, **2**, *Proc. U.P. Acad. Sc.*, **4**, etc.)

R. Vaidyanathswami has investigated the simplexes doubly incident with a quadric (*Proc. Camb. Phil. Soc.*, **22**), and the number of lines which meet 4 regions in hyperspace (*Proc. Camb. Phil. Soc.*, **22**). C. V. Hanumant Rao has investigated curves which lie on the quartic surface in space of four dimensions and the corresponding curves on the cubic surface and the quartic with a double conic. He has shown that there exist conical varieties in space of four dimensions with properties similar to those of Schur's quadrics, there being quadrics associated in a particular manner with the cubic curves on a cubic surface [*Proc. Lond. Math. Soc.*, **17** (Ser. 2)]. B. Ramamurti has established by binary apolarity methods certain fundamental properties of the rational normal surface (*Math. Annalen*, **3**). Among other important contributions of B. Ramamurti are his investigation of Desargue's configurations admitting a collineation group (*J. Lond. Math. Soc.*, **8**), the rank of a quadric related to a rational norm curve (*J. Lond. Math. Soc.*, **9**), the quadric poristically related to a norm curve (*Proc. Camb. Phil. Soc.*, **30**) and linear complexes related to a rational norm curve (*Proc. Ind. Acad. Sc.*, **1**).

D. D. Kosambi has worked in the field of Differential Geometry, mainly of higher dimensions. His important contributions consist of investigations on Differential Geometry and Calculus of Variations (*Rendiconti d. Reale Accademia Nazionale dei Lincei*), affixe-geometrical foundation of unified field theory (*Sitz. Preuss. Akademie d. Wissenschaften*), parallelism and path spaces (*Math. Zeitschrift*), path spaces of higher order (*Quart. J. of Math.*) and path-geometry and cosmogony (*Quart. J. of Math.*). R. N. Sen has discussed the connection between Levi-Civita parallelism and Einstein's tele-parallelism (*Proc. Edin. Math. Soc.*, **2**), and curvatures of hypersurfaces and rotations in hyperspace (*Bull. Cal. Math. Soc.*, **23**). J. Ghosh has discussed the differential equations corresponding to rigid bodies in the naturally curved world of De Sitter (*Tohuku Math. J.* **32**) and also certain characteristics of linear transformations of the Riemmannian space (*Ind. Phys.-Math. J.* **1**). S. M. Ganguli has written a treatise on Analytical Geometry of Hyperspaces (1914), contributed a paper on angle-concept in n-dimensional geometry (*Bull. Cal. Math. Soc.*, 1918) and the geometry of the four-fold (1934). He is also the author of a treatise on Theory of Plane Curves, Vols. 1 and 2 (1928–1932).

III. Algebra and Algebraic Equations.

A large number of authors have worked in this branch of mathematics. To mention a few of them, R. Vaidyanathswami has investigated the signs of terms in a determinant (*J. Ind. Math.

Soc., **16**), the integer roots of the unit matrix and possible periods of integer matrices (*J. Lond. Math. Soc.* **3**), an application of the permanent (*J. Ind. Math. Soc.*, **18**), an extension of determinant concept based on group characters [*J. Ind. Math. Soc.*, **1** (New Series)], a remarkable property of integers mod N. and its bearing on group theory (*Proc. Ind. Acad. Sc.*, **5**). He has investigated the rank of the double binary form [*Proc. Lond. Math. Soc.* (2), **24**], a special pencil of binary quartics (*Proc. Edin. Math. Soc.*), the theory of bilinear and double bilinear forms (*J. Ind. Math. Soc.*, **19**), the apolar invariant of bilinear forms (*Proc. Ind. Acad. Sc.*, **1**) and the null pencil of binary quartics (*Proc. Lond. Math. Soc.*, **23**). He has also discussed the quadratic reciprocity of polynomials (*J. Ind. Math. Soc.*, **17**). S. Chakravarti has written a number of papers on determinants, including discussions on two pairs of factorable continuants (*Bull. Cal. Math. Soc.*, **15**), evaluation of factorable continuants of Muir (*Bull. Cal. Math. Soc.*, **17**), and a few factorable continuants and a theorem in determinants (*Ind. Phys.-Math. J.*, **5**). M. B. Rao and M. V. Ayyar have written on the evaluation of two functional determinants (*J. Ind. Math. Soc.*, **16**) and evaluation of persymmetrics (*J. Ind. Math. Soc.*, **17**). N. N. Ghosh has a paper on a class of determinants having geometrical applications (*Bull. Cal. Math. Soc.*, **28**). S. S. Pillai has discussed a theorem concerning the primitive periods of integer matrices. K. Rao has investigated the invariant factors of a certain class of linear substitutions (*J. Ind. Math. Soc.*, **19**). Narasinga Rao has discussed Boolean matrix algebra (*J. Ind. Math. Soc.*, **18**). M. Gupta has investigated the question of substitution and equivalence of two forms (*Bull. Cal. Math. Soc.*, **22**). S. Chowla has investigated the irrational indefinite quadratic forms (*Proc. Ind. Acad. Sc.*, **2**) and the expression for the class number of binary quadratic forms (*J. Ind. Math. Soc.*, **18**).

P. O. Upadhyaya has a large number of papers in the field of algebraic equations and polynomials, published in various Indian and foreign journals. He has also investigated the cyclotomic hepta-section for the prime 43 (*Annals Math.*, **23**) and the quinquisection for all primes of the form $10n+1$ between 1900 and 2100. He has a paper on an equation of the eighth degree with Caylean property (*Tohuku Math. J.*, **24**), on an Abelian equation (*Tohuku Math. J.*, **24**) and on the quinquisection of every prime of the form $10n+1$ between 100 and 500 (*Proc. Lond. Math. Soc.*, **20**). For the work of S. Ramanujam in this branch, reference may be made to his Collected Papers. M. T. Naraniengar has a number of contributions in the Journal of the Indian Mathematical Society including the discussion of certain important properties of polynomials (*J. Ind. Math. Soc.*, **5**), cyclic equations (*J. Ind. Math. Soc.*, **1**), cyclotomic equations (*J. Ind. Math. Soc.*, **7**) and a special class of equations of the form

$$\phi[\phi\{\phi(x)\}]-x=0,$$

which is written for brevity as

$$\phi^3(x)-x=0.$$

He proves that if n is prime, then

$$[\phi^n(x)-x]=\{\phi(x)-x\}\pi\{f(x)\},$$

where $f(x)$ is a cyclic expression of the nth degree (*J. Ind. Math. Soc.*, 7).

IV. Differential and Integral Equations.

S. C. Dhar has investigated the solutions of Mathieu equation in a series of papers (*Bull. Cal. Math. Soc.*, **10**, **18** ; *American J. of Math.*, **45** ; *Tohuku Math. J.*, **19** ; *J. Department of Science, Cal. Univ.*, **3** ; *J. Ind. Math. Soc.*, **16**) and these have been collected together in a book 'Mathieu Functions'. He has given several expressions of Mathieu functions in terms of Bessel functions and the converse problem of expressing Bessel functions in terms of Mathieu functions has been attempted by N. A. Shastri (*J. Ind. Math. Soc.*, **1**). R. S. Varma has investigated the periodic solutions of the equation

$$\frac{d^2y}{dx^2}+(A+16q\cos 2nx)y=0,$$

which reduces to Mathieu equation when $n=1$ (*J. Ind. Math. Soc.*, **18**). J. L. Sarma has discussed the solution of Lame's equation by means of $\wp$-function (*Bull. Cal. Math. Soc.*, **23**).

C. N. Srinivasienger has written a series of papers on singular solutions of differential equations of the first order (*Tohuku Math. J.*, **30**, **41**) and of the second order (*J. Ind. Math. Soc.*, **20**). He has also discussed the singular solutions of simultaneous ordinary differential equations (*Proc. Ind. Acad. Sc.*, **1**) and the special integrals of partial differential equations of the first order in three variables. M. R. Siddiqi has contributed a series of papers on non-linear partial differential equations. He has proved that one and only one regular solution of each of the non-linear partial differential equations

$$\frac{\partial^2 u}{\partial x^3}-\frac{\partial u}{\partial t}=\sum_{r}^{\infty}p_r(x,t)u^r,$$

$$\frac{\partial^2 u}{\partial x^2}-\frac{\partial u}{dt}=\sum^{1\cdots\infty}p_{r,s}(x,t)u^r\left(\frac{\partial x}{\partial x}\right)^s,$$

exists which satisfies the boundary conditions :

$$u(o,t)=u(\pi,t)=0,\ u(x,o)=f(x).$$

(*Math. Zeit.*, **35**.)

He has also discussed an infinite series of integrals involving Sturm-Liouville eigen-functions (*Bull. U.P. Acad.*, **3**), the equation of heat-

conduction in wave-mechanics (*J. Ind. Math. Soc.*, **20**), Cauchy's problem in a non-linear partial differential equation of hyperbolic type (*Proc. Camb. Phil. Soc.*, **31**), and certain infinite series of Integrals (lecture delivered to the *Société mathématique de France*, 1936). He has discussed the equations

$$\frac{\partial}{\partial x}\left\{ p(x)\frac{\partial u}{\partial x} \right\} - \frac{\partial u}{\partial t} = u^2,$$

$$\frac{\partial}{\partial x}\left\{ p(x)\frac{\partial u}{\partial x} \right\} - \frac{\partial u}{\partial t} = u\frac{\partial u}{\partial x}$$

for boundary conditions of the first type and he has proved that one and only one solution of each of the two equations exists which can be expanded in a series of Sturm-Liouville eigen-functions. He has investigated the theory of an infinite system of non-linear integral equations (*Proc. International Congress of Math.*, Oslo, 1936) and the theory of non-linear partial differential equations (*Proc. British Assoc. for the Advancement of Science*, 1936). He has extended the method of integral equations and successive approximations to the more general equation

$$\frac{\partial}{\partial x}\left\{ p(x)\frac{\partial u}{\partial x} \right\} - \frac{\partial u}{\partial t} = \sum_{r,s}^{1\cdots\infty} p_{r,s}(x, t)\, u^r \left(\frac{\partial u}{\partial x}\right.$$

The existence and uniqueness of the solution for the first boundary problem is established and the result is extended to other cases (*Comptes Rendus*, **203**).

J. C. Swaminaryan has discussed a generalized form of Clairaut's equation (*J. Ind. Math. Soc.*, **4**). C. N. Srinivasiengar has proved a theorem concerning the *p*-discriminant (*Bull. Cal. Math. Soc.*, **25**) and has also written a few notes (*J. Ind. Math. Soc.*, **17**, *Mysore Univ. J.*, *Math. Gazette*, 1929). H. N. Datta has discussed the theorem of Lie relating to the theory of intermediate integrals of partial differential equations of the second order (*Bull. Cal. Math. Soc.*, **15**). He has written two other papers on the construction of partial differential equations of the second order satisfying assigned conditions (*Bull. Cal. Math. Soc.*, **15**, **16**). G. Prasad has investigated the numerical solution of Integral Equations and of Partial Differential equations and his work is embodied in the papers on the numerical solutions of Integral Equations (*Proc. Edin. Math. Soc.*, 1923) and on the numerical solution of Partial Differential Equations (*Phil. Mag.*, **9**).

V. Theory of Functions and Infinite Series.

K. Ananda Rau supplied an important step in the proof of a theorem of Hardy (*Proc. Lond. Math. Soc.*, **17**) and has considered the usual Abelian theorem for power series in connection with

ordinary Lambert's series (*Proc. Lond. Math. Soc.*, **19**). In a note on a property of Dirichlet's series, he proves that if $f(s) = \Sigma a_n e^{-\lambda ns}$, $s = \sigma + it$, converges for $\sigma \geqslant \sigma_0$ while $f(s)$ is regular for $\sigma > \nu > \sigma_0$, then $f(\beta + it)$ cannot tend to a definite limit as $|t| \to \infty$, where $\beta > \nu$ is fixed (*Proc. Lond. Math. Soc.*, **19**). He has discussed the converse of the Abelian theorem (*J. Ind. Math. Soc.*, **3**), Dirichlet's series with positive coefficients (*Rend Cir. Palermo.*, **54**; *Quart. J. Math.*, **2**), an example of the summation by Riesz's Typical Means (*Proc. Lond. Math. Soc.*, **30**), and convergence and summability of Dirichlet's series (*Proc. Lond. Math. Soc.*, **34**).

Ganapathy Ayer's work is embodied in the papers relating to the rearrangement of complex series (*J. Ind. Math. Soc.*, **1**), Tauberian theorems on generalized Lambert series (*J. Ind. Math. Soc.*, **1**) and Tauberian and summability theorems on Dirichlet's series. S. Minakshisundaram has a paper on Tauberian theorems on Dirichlet's series (*J. Ind. Math. Soc.*, **2**). K. V. Iyenger has written several papers on Infinite Series, including a discussion on series whose terms as well as sum-function are continuous but which do not converge uniformly in any interval (*J. Ind. Math. Soc.*, **1**) and also on Weirstrass's non-differentiable function (*J. Ind. Math. Soc.*, **19**).

K. Ananda Rau discusses the boundary behaviour of elliptic modular functions (*Acta Math.*, **52**) and the behaviour of the theta-function near the line of singularities (*J. Ind. Math. Soc.*, **20**).

V. Ganapathy Ayer discusses the integral functions of order one and finite type (*J. Ind. Math. Soc.*, **2**) and integral functions of finite order bounded at a sequence of points (*J. Ind. Math. Soc.*, **2**). In these two papers the author discusses some generalizations of the result of Polya that ' if $f(z)$ is an integral function of order one and minimal type and $f(\pm n) = 0(1)$, $n = 1, 2, \ldots$, then $f(z)$ is a constant '. He has continued the discussion further and proved several new results (*J. Ind. Math. Soc.*, **2**). He has contributed a note on integral functions of order two, bounded at the lattice points (*J. Lond. Math. Soc.*, **11**), where he has proved that an integral function of order two and type less than $\pi/2$ bounded at the lattice points must be constant. He discusses the maximum modulus curves of holomorphic functions (*Proc. Ind. Acad. Sc.*, **4**) and the Lebesgue class of integral functions along straight lines issuing from the origin (*Quart. J. of Math.*, **7**). In the latter, he has partially generalized the classical Phragmen-Lindelot theorem. K. S. Suryanarayan has contributed a paper on composite meromorphic functions (*J. Ind. Math. Soc.*, **1**). K. V. Iyengar has discussed the generalization of Jacobi's theta-function formula (*J. Ind. Math. Soc.*, **1**) and the reducibility of the general elliptic integrals into logarithms (*J. Ind. Math. Soc.*, **1**).

H. P. Banerji has discussed a generalized force-function of Painleve's type (*Bull. Cal. Math. Soc.*, 1915), an application of the theory of functions to Dynamics (*Bull. Cal. Math. Soc.*, **8**), and Peano's function (*Bull. Cal. Math. Soc.*, **16**). He has established

Math. Zeit. **40**. *J. Lond. Math. Soc.* **6**, *Proc. U.P. Acad. Sc.* **4** ; etc. T. Vijayaraghavan has contributed a note on diophantine approximation (*J. Lond. Math. Soc.*, **2**) and converse theorems on summability (*J. Lond. Math. Soc.*, **2**). He has investigated some configurations of singular points on the circumference of the circle of convergence of a power series whose coefficients have suitable gaps (*J. Ind. Math. Soc.*, **17**). He proves the following :—

If $N(R)$ denote the number of elements in the periodic part of the simple continued fraction for $\dfrac{P+\sqrt{R}}{Q}$ where $|P|$, $|Q|$, and R are positive integers and Q divides $R-P^2$, then

$$N(R) = O(R^{\frac{1}{2}+\delta}).$$

Making use of some results of I. Schur, the author further shows that

$$N(R) = O\,(R^{\frac{1}{2}} \log R)$$

and that for infinitely many R,

$$N(R) > R^{\frac{1}{2}-\delta}, \; N(R) = O(\log R),$$

all uniformly in P and Q (*Proc. Lond. Math. Soc.*, **26**). He has given a direct and elementary proof for Schmidt's Tauberian theorem for series of real terms which are summable according to Borel's exponential method (*Proc. Lond. Math. Soc.*, **27**). He has proved that if

$$\sum^{\infty} a_n$$

is summable (A), and if for

$$q > p, \; \frac{p}{q} \to 1, \; \lim\, (s_q - s_p) \geqslant 0, \text{ then } \sum_1^{\infty} a_n$$

is convergent (*J. Lond. Math. Soc.*, **1**). He has also proved the following theorem :—

If $f(z)$ be an integral function and if

$$M(r) = \underset{|z|=r}{\mathrm{Max}}\, |\, f(z)\,| \text{ and } M'(r) = \underset{|z|=r}{\mathrm{Max}}\, |\, f'(z)\,|\,,$$

then

$$M'(r) \geqslant \frac{M(r)}{r} \cdot \frac{\log M(r)}{\log r}, \text{ for } r > r_0,$$

where r_0 is a number depending on the function f.

S. C. Mitra has a series of papers, including the investigation of certain hitherto unsolved cases of the complex multiplication of elliptic functions (*Annals Math.*, **30**), tables of complex multiplication modulii of elliptic functions (*Bull. Cal. Math. Soc.*, **19**, **21** ;

Ind. Phys.-Math. J., **2**) and also modular equations and complex multiplication of elliptic functions (*Bull. Cal. Math. Soc.*, **19**, **25**, **26**).

VI. Spherical Harmonics and the Theory of Potential.

The potentials of elliptic and ellipsoidal bodies have been investigated by N. R. Sen, who obtained by using discontinuous integrals, a method first proposed by Dirichlet, the potentials of semi-ellipsoids, semi-ellipses and in general any part of ellipses and ellipsoids in integral forms (*Bull. Cal. Math. Soc.*, **10**). In a second paper, trigonometrical series were constructed for the external potentials of elliptic cylinders (*Phil. Mag.*, **38**).

H. Sankar has discussed a new family of Definite Integrals which satisfy the differential equation associated with the parabolic cylinder (*Proc. Benares Math. Soc.*, **5**). The new family referred to above is of the form

$$E_n(z) = e^{-\frac{1}{4}z^2}.\, z^n \int e^{-t}\,(-t)^{-\frac{1}{2}} \left(1+\frac{i\sqrt{2t}}{z}\right)^1 dt.$$

He has also discussed certain other functions associated with the parabolic cylinder in Harmonic Analysis (*Proc. Benares Math. Soc.*, **6**).

K. B. Madhava has investigated Riemann's Zetafunction (*J. Ind. Math. Soc.*, **9**), asymptotic expansions of Integral functions (*J. Ind. Math. Soc.*, **9**), Legendre's relation in elliptic functions (*J. Ind. Math. Soc.*, **10**) and other functions of Legendre type (*J. Ind. Math. Soc.*, **12**). G. Prasad has investigated many properties of the parabolic cylinder functions and has obtained various expansions in connection with them. One important result is an inequality which enables one to prove the convergency of expansions obtained in terms of these functions (*Proc. Benares Math. Soc.*, **2**, **3**, **4**, **8**). H. Sircar discusses the reduction of Ferrar's associated Legendre functions and the evaluation of certain definite integrals involving them (*Proc. Edin. Math. Soc.*, **1**). S. C. Mitra has written a series of papers, including the expansion for

$$\frac{d}{dn}\,J_n(x)$$

(*Bull. Cal. Math. Soc.*, **15**), the expansion of an arbitrary function of the co-ordinates of a point on the surface of an ellipsoid in a series of ellipsoidal harmonics (*Bull. Cal. Math. Soc.*, **16**), the expansion of the product of two parabolic cylinder functions in a series of parabolic cylinder functions (*Bull. Cal. Math. Soc.*, **17** ; *Proc. Benares Math. Soc.*, **9**), a discussion of the squares of Weber's parabolic cylinder functions and certain integrals connected with them (*Proc. Edin. Math. Soc.*, **4**) and an integral equation satisfied by them (*J. Lond. Math. Soc.*, **11**). He has also established certain

new connections between Legendre and Bessel functions (*Proc. Edin. Math. Soc.*, 4; *Math. Zeit.*, 41).

VII. Theory of Numbers and Arithmetical Functions.

As early as 1912, V. Ramesam published a note on Mersenne's number $2^{71}-1$ (*J. Ind. Math. Soc.*, 4). S. Ramanujan published a paper on irregular numbers (*J. Ind. Math. Soc.*, **5**), one of his earliest works published in India, prior to his sojourn in England. For a complete list of his papers, reference may be made to 'Collected Papers of Srinivasa Ramanujan' (p. xxxii-xxxiv). H. Balakram has a series of papers on the theory of numbers, more or less of an elementary character. N. B. Mitra has discussed the converse of Fermat's theorem (*J. Ind. Math. Soc.*, **15**), and investigated the product of all numbers less than N and prime to it. In the latter paper he has given a formula for the product and has also pointed out some inaccuracies in the formulæ given by others (*J. Ind. Math. Soc.*, **14**). S. D. Chowla has published a number of papers, including a new proof of Von-Sandt's theorem (*J. Ind. Math. Soc.*, **16**), some properties of Eulerian numbers (*Tohuku. Math. J.*, **30**), a generalization of a theorem of Wolstenholme (*J. Lond. Math. Soc.*, **5**) and a note on Warings theorem on cubes (*J. Ind. Math. Soc.*, **18**). R. Vaidyanathswami has written a number of papers including the inversion of multiplicative arithmetic function (*J. Ind. Math. Soc.*, **17**), the general theory of multiplicative functions (*Atti Congress Bologna*, **2**), the identical equations of the multiplicative function (*Bull. Amer. Math. Soc.*, **36**), the theory of multiplicative arithmetic functions (*Trans. Amer. Soc.*, **33**; *Bull. Amer. Math. Soc.*, **37**) and a note on the combinatory analysis (*J. Ind. Math. Soc.*, **10**). A large number of papers have been contributed by S. D. Chowla on the theory of numbers, including a note on a conjecture of Ramanujan (*Tohuku Math. J.*, **33**), Lendesdorf's generalization of Wolstenholme's problem (*J. Lond. Math. Soc.*, **9**), a discussion of the rational solutions of $ax^n-by^n=k$ (*Ind. Phys.-Math. J.*, **3**), a theorem in Arithmetic (*J. Lond. Math. Soc.*, **9**), a discussion on abundant numbers (*J. Ind. Math. Soc.*, **1**), and a theorem on the addition of residue classes (*Proc. Ind. Acad. Sc.*, **2**).

H. Gupta's investigations include his note on a theorem of Gauss (*Proc. Edin. Math. Soc.*, **4**), discussion of the potency of $G(p^{16}-1, r)$ (*Proc. Ind. Acad. Sc.*, **2**), the minimum partition into specified parts (*American J. Math.*, **58**), and the decomposition into cubes of primes (*Proc. Ind. Acad. Sc.*, **4**). He has also a paper on the diophantine equation $m^2=\underline{|n}+1$ (*American Math. Monthly*, **43**).

VIII. Hydrodynamics.

A. C. Banerji and R. S. Verma have investigated tidal waves in canals with sinuous banks and furrowed bottom (*Proc. Camb.

Phil. Soc., 1928). They have also discussed tidal waves in canals of varying cross-sections (*Mess. Math.*, 1929).

D. K. Sen has investigated the application of Burgess's method for determining the uniform motion of an ellipsoid of revolution through a viscous liquid along its axis of revolution (*Proc. Benares Math. Soc.*, **2**). In this paper, the complete equations of motion in cylindrical co-ordinates are considered and the solution is obtained, by successive approximation. The resistance is calculated and its value to a first approximation is

$$-6\pi\mu W\alpha\left(1+\frac{3}{4}k\alpha+\frac{1}{5}\epsilon+\frac{3}{10}k\epsilon\alpha\right).$$

The solution leads to Oberbeck's and Oseen's results as particular cases. He has investigated the resistance of a sphere due to its uniform translation in a viscous liquid. (*J. Univ. Bom.*, **2**) and also the resistance of general ellipsoid moving in a viscous liquid (*J. Univ. Bomb.*, **4**).

N. N. Sen has a number of papers in hydrodynamics dealing with tidal oscillations in canals with varying breadths and depths (*Bull. Cal. Math. Soc.*, **12**). He has investigated the problem of the motion of circular vertex rings mathematically without making the assumptions that vorticity and compression are constant over the cross-section of the ring and concentrated in the circular axis (*Bull. Cal. Math. Soc.*, **23**). He has also investigated the vortex rings in compressible and incompressible liquids (*Bull. Cal. Math. Soc.*, **15**, **17**, **13**, **14**). He has a paper on liquid motion inside certain curvilimar rectangles (*Bull. Cal. Math. Soc.*, **11**). He has also investigated the motion of a viscous fluid due to the rotation of two spheroids about their common axis of revolution (*Bull. Cal. Math. Soc.*, **13**), the motion of two spheroids in an infinite liquid (*Bull. Cal. Math. Soc.*, **14**) and certain higher order tides in canals of variable section (*Bull. Cal. Math. Soc.*, **14**). B. B. Datta investigated the stability of rectilinear vortices of compressible fluid (*Phil. Mag.*, **40**). He also investigated the problem of two mutually influencing spheroidal conductors by methods analogous to the similar hydrodynamical problem of the motion of the spheroids (*Tohuku Math. J.*, **18**). B. N. Pal has investigated in motion of elongated spheroids in viscous fluid media (*Bull. Cal. Math. Soc.*, **11**) and the motion of an ellipsoid of revolution in a viscous fluid in the light of Prof. Oseen's objection on Stoke's treatment of the case of the sphere (*Bull. Cal. Math. Soc.*, **10**). K. K. De has worked out the case of vortex motion near semi-circular boundaries and infinite straight boundaries with semi-circular projections (*Bull. Cal. Math. Soc.*, **21**). M. Ray has investigated the motion of viscous fluid due to vibrations of an infinite cylinder (*Bull. Cal. Math. Soc.*, **25**), due to motion of a disc (*Phil. Mag.*, **21**), and due to vibrations of infinite elliptic cylinders

(*Zeit. Angew. Math. u. Mech.*, **16**) and has also discussed the stability of a circular vortex. Kelvin's calculations on the vibrations of a columnar vortex with uniform vorticity are extended to a non-uniform vorticity. Also a circular cylinder inside the vortex, coaxial with it in its undisturbed position is made to execute small circular vibrations and it is shown that if the disturbance produced is irrotational, the original velocity must have been uniform (*Bull. Cal. Math. Soc.*, **27**). He has also investigated the motion of an infinite elliptic cylinder in fluids with constant vorticity (*Proc. Roy. Soc.*, *A*, **158**).

N. M. Basu and H. Sircar have investigated the velocity potential of the sound waves due to prescribed vibrations of a cylindrical surface in the presence of a rigid and fixed cylindrical obstacle (*Bull. Cal. Math. Soc.*, **18**). H. Sircar obtains an approximate solution for the vibrations of a gas enclosed between a rigid and fixed spheroid and a concentric sphere vibrating with a prescribed normal velocity (*J. Ind. Math. Soc.*, **18**). He has also contributed a paper on the motion due to a system of bodies (*Bull. Cal. Math. Soc.*, **22**), including the motion of an ideal fluid due to the steady translation of two parallel circular discs and the steady slow rotation of two circular discs in a viscous fluid.

S. C. Mitra has investigated the steady translation and rotation of a sphere of viscous liquid with a solid core in another viscous liquid (*Bull. Cal. Math. Soc.*, **14**), the motion set up in a viscous liquid by the rotation of a cylinder whose cross-section is an elliptic limaçon (*Mess. Math.*, **54**), and the motion generated in a viscous liquid by the translation of certain quartic cylinders (*Proc. Ind. Assoc. Cult. Sc.*, **9**).

B. M. Sen, in his paper entitled 'Waves in canals and basins' (*Proc. Lond. Math. Soc.*, **26**), has found a solution involving an orbitrary function, for the equation which holds at the free surface and the equation of continuity. In particular, a train of simple harmonic waves moving in a parabolic cylindrical canal have been found, which are independent of the depth of the canal. For basins also, a general solution for the boundary has been found, of which a hyperbolic paraboloid and a cone of the second degree are special cases.

S. Ghosh has worked out the steady motion of a viscous liquid due to the translation of a tore parallel to the axis (*Bull. Cal. Math. Soc.*, **18**). N. M. Basu has discussed the liquid motion inside rotating arcs of three and four confocal parabolas (*Bull. Cal. Math. Soc.*, **11**).

IX. Theory of Elasticity.

An important contribution to the theory of Elasticity has been made by B. R. Seth in a paper 'Finite strain in elastic problems' (*Phil. Trans. Roy. Soc.*, **234A**). The theory of finite strain has been developed on the hypothesis that the second order

terms in the components of strain may not be neglected. Like the body-stress equations these components have been referred to the actual position of a point P of the material in the strained condition, and not to the position of a point considered before strain. The method has been applied to quite a few cases, including that of a rectangular plate bent into the form of a right cylinder. It is interesting to note that the tension-stretch curve is now not a straight line as in the ordinary theory, but is more like that found in practice for some materials. The important case of the state of strain in an India rubber tubing turned inside out together with a few further applications has also been investigated [*Proc. Roy. Soc.*, (A), **156**]. A very general solution for the important class of two-dimensional physical problems in which the boundary consists of two straight lines only, has been investigated by Seth (*Phil. Mag.*, **20**) and various applications of these solutions have been made by him (*Quart. J. Math.*, **5**; *Proc. Camb. Phil. Soc.*, **30** and *Phil. Mag.*, **22**). The flexure problem for an isosceles right-angled triangle has been discussed by Seth (*Proc. Lond. Math. Soc.*, **37**), who has also obtained solutions for other triangular prisms (*Proc. Lond. Math. Soc.*, **41**). The case of a prism whose cross-section is a rhombus has been discussed by him (*J. Lond. Math. Soc.*, **10**). He has also given a very complete solution for the flexure of a hollow staff (*Proc. Ind. Acad. Sc.*, **4**).

S. Ghosh has made a series of important and interesting contributions to the theory, including solutions corresponding to plane strain and stress in rotating elliptic cylinders and discs (*Bull. Cal. Math. Soc.*, **19**), solution of the flexure problem of a beam whose cross-section consists of (1) a semi-ellipse bounded by its minor axis, and (2) an ellipse and two confocal hyperbolas (*Bull. Cal. Math. Soc.*, **27**), the discussion of the vibrations of a circular ring in which the term corresponding to the rotatory inertia is not neglected (*Bull. Cal. Math. Soc.*, **27**), the solution of the problem of plane strain in an infinite plate with an elliptic hole (*Bull. Cal. Math. Soc.*, **28**), a problem relating to an elastic circular plate (*Bull. Cal. Math. Soc.*, **16**), certain solutions and applications of the equation $\nabla_1{}^4 w = 0$ (*Bull. Cal. Math. Soc.*, **16**), and the bending of a loaded elliptic plate. He has developed a method of application of elliptic co-ordinates for a class of elastic problems (*Trans. Am. Math. Soc.*, **32**) and has investigated certain solutions relating to the problem of dislocation in bodies with circular boundaries (*Bull. Cal. Math. Soc.*, **17**). He has also investigated the stress and strain in a rolling wheel (*Bull. Cal. Math. Soc.*, **25**).

J. Ghosh discussed a case of strain in a gravitating heterogeneous sphere (*Bull. Cal. Math. Soc.*, **12**). He has also investigated several problems of vibration, including the torsional vibrations of a tube (*Bull. Cal. Math. Soc.*, **13** and *Handbuch der Physik*, Bd. VI), vibrations of an elliptic plate (*Proc. Edin. Math. Soc.*, 1926), longitudinal vibrations of a hollow cylinder (*Bull. Cal.

Math. Soc., **14** and *Handbuch der Physik*, Bd. VI) and the vibrations of a rotating circular ring and of a rotating rod (*Bull. Cal. Math. Soc.*, **14** and *Handbuch der Physik*, Bd. VI). He has also given an alternative discussion of the stability of a loaded strut (*Bull. Cal. Math. Soc.*, **16**).

N. M. Basu and H. M. Sengupta have worked out the case of strain in a rotating elliptic cylinder (*Bull. Cal. Math. Soc.*, **18**). By an application of the calculus of variations to the theory of elasticity, he works out the deflection of a uniformly loaded square membrane by Ritz's method (*Phil. Mag.*, **10**) and the result is tested by consideration of an associated problem. The twisting couple of an elastic prism of square section when subjected to torsion about its axis is calculated similarly and is compared with the Saint Venant result. The results are correct to a high degree of approximation. In the paper on 'Torsion problem of the theory of elasticity' (*Phil. Mag.*, **10**), N. M. Basu gives a general method, based on the calculus of variations, which directly determines the torsion-function and is applicable to a wide class of problems and is specially suitable for numerical calculations. A special feature of this method is that the error can always be calculated by an associated problem. He jointly with H. M. Sengupta has also discussed the bending of a thin elastic circular plate due to a certain distribution of load (*Tohuku Math. J.*, **33**).

B. Sen has worked out a number of problems, including calculation of stresses in a bent beam due to a small elliptical hole on the neutral axis (*Phil. Mag.*, **12**), torsional oscillations of a conical rod when a cap extending from the apex is maintained at rest (*Zeit. Tech. Physik*, **14**), alternative discussions on the bending of loaded plates (*Ind. Phys.-Math. J.*, **5**; *Phil. Mag.*, **16**). In a paper entitled 'Effect of small cavities and cracks in a cylinder twisted by torsional and shearing stresses' (*Zeit. Angew. Math. u. Mech.*, **13**), B. Sen has calculated the stresses in a circular cylinder twisted by terminal couples, the shaft having a small spherical or spheroidal cavity on the axis or a linear flow extending from one end to the other along the axis. He has worked out the case of stresses in a rotating disc whose thickness vary according to a simple law (*Phil. Mag.*, **19**), torsional vibrations of cylindrical rods under variable forces (*Ind. Phys.-Math. J.*, **6**), and the stresses in solids of revolution due to friction acting on their curved surfaces (*Ind. Phys.-Math. J.*, **7**). He has contributed several other papers on elasticity, chiefly in the *Bulletin of the Calcutta Mathematical Society*.

H. M. Sengupta has contributed several papers, which include the determination of stresses and strains in a semi-infinite elastic plate bounded by a straight edge under the action of a couple at any point on the straight boundary (*J. Ind. Math. Soc.*, **18**). It is found that the lines of stress are systems of orthogonally intersecting cardioids. He has worked out the case of a thick elastic plate

on of whose faces is subjected to a given distribution of pressure (p_0xy), and applied the results to the case of a circular plate (*J. Ind. Math. Soc.*, **18**). He has further extended his solutions to the case of an elliptic plate (*Ind. Phys.-Math. J.*, **1**).

The late Dr. P. Das contributed a number of papers on the vibrations of the pianoforte strings. In one paper (*Ind. Assoc. for Cult. Sc. Proc.*, **7**), he extended Kaufnann's work so as to give more accurate results by working out the successive functional solutions. A graph was plotted showing the pressure of the hammer, which increases discontinuously by sudden jumps of magnitude $2\rho v_0 c$. The graph bears a close resemblance to those obtained by C. V. Raman and S. K. Banerji by a different method. The work was continued in another paper (*Ind. Assoc. for Cult. Sc. Proc.*, **9**). He published papers on the energy of plucked string (*J. Physics*, **1**), the theory of the elastic pianoforte hammer (*Proc. Phys. Soc.*, **40**), and the struck string (*Phil. Mag.*, **6**), in which he replied to certain criticisms of his earlier work. He investigated the theory of the Clarinet in an interesting paper (*Ind. J. Physics*, **6**) and discussed the maintained vibrations of the harmonium-reed (*Ind. J. Physics*, **3**) due to steady pressure of the bellows.

X. Relativity Theory.

V. V. Narlikar has contributed a number of papers on the theory of relativity. He has worked out a generalization of the Swarzschild solution (*Phil. Mag.*, **22**), and has obtained some new properties of the world-trajectories in Milne's theory on the assumption that the trajectories are described by particles possessing mass (*Phil. Mag.*, **20**). In a note on Lorentz transformation, he shows that the linearity may be deduced as a consequence of the wave-equation of light and that it is unnecessary to advance the argument of homogeneity in space-time to account for it (*Proc. Camb. Phil. Soc.*, **28**). He has contributed a note on the isotsopic solution, in which the condition $T_1^1 = T_2^2 = T_3^3$ is replaced by another suggested by Walker (*M.N.R.A.S.*, **95**), and has also discussed the question of stability of a particle in a gravitational field (*M.N.R.A.S.*, **96**).

N. R. Sen worked out the covariant analogues of the equation

$$\left(\frac{\partial V}{\partial n}\right)_2^1 = 4\pi\sigma,$$

and formulated a criterion for testing whether discontinuities of derivatives of the metric tensor on a surface are spurious, which can be swept away by co-ordinate transformation, or real, being due to a surface density of matter (*Ann. d. Physik.*, **73**). By the introduction of the λ term in the field equations it was shown that the De Sitter world is the limiting case of the gravitational field within a spherical shell (*Ann. d. Physik*, **74**). It was shown

that Einstein's modified field equations (with $\frac{1}{4}g_{ik}R$ instead of $\frac{1}{2}g_{ik}R$) have the consequence that an electron of finite radius must have three quarters of its total energy of electromagnetic origin and one quarter of gravitational origin (*Zet. f. Physik*, **40**), and Klein's five-dimensional wave equations cannot represent the electron wave phenomenon in a gravitational field as it fails to give the expected red displacement of spectral lines (*Zeit. f. Phys.*, **66**). The equilibrium of incompressible sphere was investigated in a paper in *M.N.R.A.S.*, **94**. It was shown that for a given density there is sphere of maximum radius, and another of maximum gravitational mass. In contrast with the classical solution for a given density and radius, there are two spheres of different masses. A sphere of density $3 \cdot 10^{12}$ gm./cm.^{3} would have a maximum radius of only 1·33 km., and a minimum mass nearly 24 times that of the sun. N. K. Chatterjee (*M.N.R.A.S.*, **96**) has shown that for a given density and radius, there are in some cases two and in others three spheres. N. R. Sen and N. K. Chatterjee have investigated the equilibrium of polytropes from the standpoint of general Relativity (*Zeits. f. Astrophys.*, 7). It was found that for high densities the results differ considerably from those obtained by using classical mechanics. S. C. Kar has worked out a solution of Einstein's gravitational equation for the field of uniformly charged and infinite material plane (*Phys. Zeits.*, **27**). Later in another paper (*Phys. Zeit.*, **28**) he made an attempt to unify Electrodynamics with Einstein's theory of gravitation. A new electrodynamics based on space time rotation and giving Lorentz force correctly was developed and ultimately combined with Einstein's theory of gravitation.

B. C. Mukherjee has shown (*Ind. J. Phys.*, **10**) that the linearity of (one dimensional) Lorentz transformation is a necessary consequence of the invariance of the wave equation and the postulate that if the velocity of the first reference system with reference to the second is v, that of the second with reference to the first is $-v$. In *Zeit. f. Phys.*, **101**, Mukherjee has solved the electromagnetic wave equations in Friedmann space and has deduced the conclusions that the wave propagation takes place with constant velocity and the wavelength decreases as the wave progresses, suggesting the immutability of a photon.

The work on Relativistic cosmology by N. R. Sen and N. K. Chatterji will be reported elsewhere.

J. Ghosh investigated the gravitational field of a heterogeneous fluid sphere in which the density diminished from the centre outwards according to a simple law (*Proc. Edin. Math. Soc.*, 1926). He also discussed the field of an ideal fluid in which the ratio of pressure to density may be assumed to be unity (*Bull. Cal. Math. Soc.*, **20**). He obtained solutions of the gravitational equations for fluid mass, in which the radial and transverse stresses were linearly related (*Tohuku Math. J.*, 1929). It was found that the

solutions in these general forms included as special cases the solutions of Einstein, De Sitter and Schwarzschild. He investigated the gravitational field of an electron on the basis of the equation $K_{pq}-\frac{1}{4}g_{pq}k=-8\pi E_{pq}$ and found that the solution contained a term which exactly corresponds to the De Sitter term λ interpolated in Einstein's equations (*Zeit. f. Physik*, **85** ; *Nature*, July, 1933). He proved subsequently that in the fundamental cases, viz., the field of an empty space, the field of a material particle and the field of an electron, and also in the cases of certain forms of radial symmetry, the solutions of the equations with $\frac{1}{4}g_{pq}$ instead of $\frac{1}{2}g_{pq}$ yielded the De Sitter term (*Zeit. f. Physik*, **94** ; *Nature*, July, 1935). B. Datta has extended one of the solutions obtained by J. Ghosh to the case of a fluid sphere with a nucleus at the centre (*Zeit. f. Physik*, **103**).

S. M. Sulaiman has put forward a new theory of relativity, which he has been expounding in a regular series of papers published in the *Proc. Nat. Acad. Sc., Allahabad* and in the *Indian Physico-Math. J.* He starts with the fundamental assumption that the velocity of gravitation is finite. Applying this correction in Newtonian Mechanics he has derived the law of gravitational attraction as

$$\frac{GM}{r^2} \quad \frac{3GMh^2}{D^2} \cdot \frac{1}{r^4},$$

where M is the gravitating mass at the origin, D is the velocity of gravitational influence and G is the gravitational constant. Treating the extra term as a small disturbing force,

(1) the advance of the perihelion comes to

$$\frac{6\pi\mu^2}{D^2h^2}.$$

This is identical with Einstein's value in Relativity, which has been confirmed by Newcomb's observations.

(2) The deflection of light particle from a star past the Sun lies between

$$\frac{16\mu}{3D^2R} \text{ and } \frac{6\mu}{D^2R}.$$

This lies between 4/3 and 3/2 times Einstein's value, the larger values having been confirmed by Freundlich.

(3) The spectral shift of light from any part of the Sun is

$$\frac{\mu}{D^2a}(1+\sin^2\alpha),$$

where R is the shortest distance from the Sun, a is its radius and α is the angle between the line of sight and the radius, $\mu = GM$, and D equals the velocity of light.

This yields the same value as Einsteins at the centre, but gives double the value at the edge. The larger value has been confirmed by Evershed.

Equations of the orbit for $u = \frac{1}{r}$ in terms of θ and θ in terms of u have been obtained in Weierstrass's function. The Two Bodies Problem is simple. The potential function for the Three Bodies Problem also has been obtained.

He is also engaged in developing a new Theory of Light, a part of which appears in *Ind. Phys.-Math. J.*, 8 (1937).

XI. Statistics.

Researches in theoretical statistics was started in India about a quarter of a century ago by Sir Gilbert Walker. In his earlier work on the correlation of seasonal variations in weather, Sir Gilbert Walker had been using the ordinary expression for the probable error of coefficient of correlation. He however soon realized that this test was applicable only to correlation coefficients selected at random, and not to those selected out of a number on account of their high magnitude. In 1914 he published the Walker test which is applicable to such cases [*Mem. Ind. Met. Dept.*, **21** (9)]. Recently this test has been extended to the case of more than one coefficient of correlation by S. R. Savur (*Met. Dept. Sc. Notes*, **49**). The next step in judging the reliability of correlation coefficients which had not been selected at random but because of other considerations was taken in 1931 by C. W. B. Normand. He devised a simple performance test by which the significance of any coefficient of correlation can be judged on the evidence of actual success in forecasting achieved in practice (*Quar. Jour. Roy. Met. Soc.*, **58**). Applications of the performance test to various meteorological problems have been also considered by Savur [*Ind. Jour. Phys.* 8 (1) ; *Sankhyā*, **2** (1)]. He has recently considered a problem in inverse probability [*Proc. Ind. Acad. Sc.*, **5** (3)], and has independently [Thompson, *Ann. Math. Stat.*, 8 (3)], pointed out the advantage of using the median for tests of significance, the results being independent of the nature of the parent populations from which these samples are drawn.

Researches in theoretical statistics are also proceeding in the Statistical Laboratory, Calcutta. P. C. Mahalanobis investigated the effect of errors of observations on coefficients of correlation in connexion with the localization of the seat of activity in upper air [*Mem. Ind. Met. Dept.*, **24** (1) and **24** (2)]. Later he found it necessary to devise a coefficient (called D^2) for measuring the amount of differentiation existing between different statistical groups [*J.A.S.B.*, **23** (3)]. A little later he gave the moment coefficients of D^2 and showed that the distribution was of Pearsonian

Type III when the two samples are drawn from the same normal population. Results of extensive artificial sampling experiment corroborating the theoretical formulae was also given at the same time [*J.A.S.B.*, **26** (4)]. The problem of measuring the degree of divergence between samples drawn from non-identical populations was reviewed generally in another paper [*Proc. Nat. Inst. Sc. Ind.*, **2** (1)]. R. C. Bose found the exact distribution of D^2 on the assumption that the population variances and covariances are identical and known [*Sankhyā*, **2** (2)]. S. N. Bose, in the course of his investigations on the moment coefficients of D^2 [*Sankhyā*, **2** (4)] reached certain fundamental differential and integral equations connected with the normal multivariate correlated population [*Sankhyā*, **3** (2)]. These two papers are likely to mark a new starting point in researches in the general theory of multi-dimensional frequency distributions.

R. C. Bose published a short note on the application of hyperspace geometry in statistics [*Sankhyā*, **1** (2, 3)]. More recently hyperspace geometry, matrix and multi-dimensional vector methods were used by P. C. Mahalanobis, R. C. Bose and S. N. Roy [*Sankhyā*, **3** (1)], for constructing a new type of rectangular co-ordinates with the help of which most of the sampling distributions connected with the normal multivariate correlated populations can be obtained in a simple manner.

S. S. Bose gave the exact distribution of the ratio of variances (Fisher's 'z') for the case of correlated variates [*Sankhyā*, **2** (1)].

An early table for L-tests was calculated by P. C. Mahalanobis [*Sankhyā*, **1** (1)] and was followed by S. S. Bose's tables for testing the significance of linear regression [*Sankhyā*, **1** (2, 3)] and Mahalanobis's table of random samples from a normal population [*Sankhyā*, **1** (2, 3)]. Extensive tables for the D^2-statistic have also been completed and will be shortly published.

Very recently papers on special problems have also appeared; *e.g.* A. A. Krishnaswamy Ayyangar's papers on the moment coefficients of the hypergeometric series [*Biom.* 1926, 1934; *Jour. Ind. Math. Soc.*, **1** (4)]; S. Subramanian's note on a property of partial correlation (*J.R.S.S.*, **98**); U. S. Nair's paper on the standard error of Gini's mean deviation (*Biom.*, **28**); K. C. Basak's application of tribonometrical functions in the calculus of finite differences [*Sankhyā*, **2** (4)]; and K. Raghavan Nair's study of lagging correlations between two random series (*J.R.S.S.*, **99**) and notes on Karl Pearson's work on limits of marked members in a sample (*Biom.* **28**) and the exact distribution of λ_n [*Sankhyā*, **3** (2)].

R. S. Koshal applied the method of maximum likelihood for the improvement of curves fitted by the method of moments [*J.R.S.S.*, **96** (2)]. N. K. Adyanthaya worked on small samples drawn from non-normal populations (*Biom.* **20A**, **21**), A. V. Sukhatme on the theory of sampling from a finite population [*Sankhyā*, **2** (1)] and P. P. N. Nayer on the application of Neyman

and Pearson's *L*-tests (*Biom. Res. Mem.*, **1**). P. V. Sukhatme developed tests of significance for samples drawn from an exponential population (*Biom. Res. Mem.*, **1**), the sampling distributions of which are identical with those of the corresponding tests for normal populations. He has also worked on the theory of representative sampling first developed by J. S. Neyman (*J.R.S.S.*, 1935) and on partition functions with R. A. Fisher.

XII. Miscellaneous.

Besides the work under different heads detailed above, mention must be made of the work of S. K. Banerji who is the author of a large number of original papers in the field of Seismology, Meteorology, Terrestrial Magnetism, etc., which will be reported elsewhere. Mention may be made here of a few of his theoretical papers, including 'The Electric Field of Overhead Thunderclouds' (*Phil. Trans. Roy. Soc.*, **231**A), The Depth of Earthquake Focus (*Phil. Mag.*, **49**), Microscisms associated with disturbed weather in the Indian Seas (*Phil. Trans. Roy. Soc.*, **229**A), propagation of elastic waves in isotropic heterogeneous medium (*Bull. Cal. Math. Soc.*, **12**), discontinuous fluid motion under different thermal conditions (*Ind. J. Physics*, **7**), the effect of mountain-ranges on air motion (*Ind. J. Phys.*, **5**), vortices on the monsoon front (*Nature*, **122**), diffraction phenomena in the testing of optical surfaces (*Nature*, 1917), aerial waves generated by impact (*Phil. Mag.*, **32**, **35**), vibrations of elastic shells partly filled with liquid (*Phys. Rev.*, **13**). spherical waves of finite amplitude (*Bull. Cal. Math. Soc.*, **11**), electromagnetic waves due to electrical oscillations on the surface of a thin spherical shell in the presence of a non-concentric conducting sphere (*Bull. Cal. Math. Soc.*, **5**), harmonics associated with an ellipsoid (*Bull. Cal. Math. Soc.*, **10**), notes on Legendre and Bessel functions (*Bull. Cal. Math. Soc.*, **12**, **8**; *J. Ind. Math. Soc.*, **14**), the artificial vibrations of ground (*Ind. J. Phys.*, **8**) and electric-charges of rain drops (*Nature*, **130**).

D. P. Banerji has published several papers on Legendre Functions (*Ind. Phys.-Math. J.*, **4**), electrification of two and three co-axial circular and elliptic discs (*Ind. Phys.-Math. J.*, **5**, **8**) and certain motions of viscous air past given obstacles (*Ind. Phys.-Math. J.*, **7**).

The History of Mathematics has been the subject of research of a number of authors, among whom are B. Datta, who has just completed the first volume of a history of the early Indian Mathematics and S. K. Ganguli, who is the author of a number of important papers on Ancient Indian Mathematics. A. A. Krishnaswami Ayyanger and P. C. Bhattacharya are also authors of a large number of papers on Hindu Astronomy.

XIII. JOURNALS AND SOCIETI...

The two societies which have been entirely devoted to mathematics in India are the Calcutta Mathematical Society and the Indian Mathematical Society, founded almost simultaneously in 1907-8. The journals published by them are respectively the *Bulletin of the Calcutta Mathematical Society* and the *Journal of the Indian Mathematical Society*. Besides these, mathematical papers, almost on all subjects, appear, in some cases quite regularly, in the following journals : *Indian Journal of Physics ; Proceedings of the Indian Academy of Sciences, Proceedings of the National Academy of Sciences, Proceedings* and *Transactions of the National Institute of Sciences, Scientific Notes of the Meteorological Department, The Indian Physico-Mathematical Journal, Bombay University Journal, Bulletin of the Patna Science College Philosophical Society, Central Board of Irrigation Publications* and *Mysore University Half-Yearly Journal.*

In conclusion the author would like to express his heartfelt thanks to the gentlemen who have kindly assisted him in compiling the materials and in particular to Dr. J. Ghosh for his unstinted assistance in compiling and arranging them.

PROGRESS OF CHEMICAL RESEARCH IN INDIA DURING THE PAST TWENTY-FIVE YEARS.

By

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Contents

I. Introduction.

During the last quarter of a century, the need for scientific research has gained wider recognition in India due, in no small measure, to the efforts of the Indian Science Congress. The pioneer researches of Sir P. C. Ray and his pupils at the Presidency College, Calcutta, created a spirit of enquiry among young chemists which in the early years was well fostered by Watson at Dacca and by Travers and Sudborough at the Indian Institute of Science, Bangalore. The facilities for chemical research were considerably increased in the period immediately following the Great War, and there are now well-equipped laboratories in the Universities of Calcutta, Dacca, Benares, Allahabad, Punjab, Aligarh, Bombay, Madras, Patna, Nagpur, Hyderabad and Waltair and in the Indian Institute of Science, Bangalore. Facilities for biochemical research are now available at the All India Institute of Hygiene, Calcutta, the School of Tropical Medicine, Calcutta, and at the Institute of Nutrition, Coonoor. The Cotton Technological Laboratory at Bombay, the Institute of Sugar Technology at Cawnpore, and the Lac Research Institute at Ranchi are examples of institutions intended for solving problems of specific industries. Besides the above, the Agricultural and Industries Departments of the Central and Provincial Governments have become more keenly alive to the needs of research and are maintaining a fair number of research laboratories.

Accordingly, chemical researches in India during the period under review have, as is to be expected, proceeded along many directions and have produced a literature which cannot possibly

be summarised with any semblance of justice in the space at the disposal of the author. He, therefore, feels called upon to apologise to the numerous workers in India whose researches lay in directions other than those included in the present survey or whose work could not be mentioned for want of space. A section on agricultural chemistry is not included in this report in the hope that the chapter on Agricultural Research will deal with these problems more fully. An apology is also made to the possible readers of this report who would unavoidably find the description given below either sketchy or even unreadable. Such reviews can rarely escape an inherent defect—defect due to the inclusion of large amount of materials, which are not interrelated and cannot be welded into an organic whole. Even then, the author is conscious that he has exercised his discretion in a way which is apt to be described as arbitrary or unbalanced.

The thanks of the author are due to his colleagues Dr. J. K. Chowdhury, Dr. S. S. Guha Sarkar and to Dr. K. P. Basu for their willing help and for their considerable share in the preparation of the report. He also takes this opportunity for thanking his friends Professors J. N. Mukherjee, B. B. Dey, H. K. Sen, J. N. Roy, M. Quereshi, S. S. Joshi, B. C. Guha, P. C. Guha, V. Subrahmanyan, T. S. Wheeler, P. R. Ray and Messrs. P. C. Banerjee, T. P. Banerjee, and B. C. Kar for furnishing the materials which have been freely incorporated in this report.

II. Physical Chemistry.

Induced and catalysed reactions

Researches in physical chemistry have been undertaken in several laboratories with a view to elucidate the mechanism of chemical reactions, taking place in the dark and under the influence of light and electric discharge. Early in 1915, Dhar began his important studies on induced reactions, and observed that organic substances like oxalic, malonic, and hydroxy acids, hydrazine hydrochloride, etc. could reduce at ordinary temperatures, salts of mercury, silver, gold and copper in presence of many oxidising agents acting as inductors, the amount of reduction being the greater the larger the amount of inductor and actor. A generalisation of considerable value which we owe to Dhar and his collaborators is the rule that the temperature coefficient of an uncatalysed reaction is much higher than that of the same reaction in presence of a positive catalyst. Thus, for example, the velocity of reaction between chromic acid and formic acid is considerably increased by the presence of sulphuric acid, but the temperature coefficient of the reaction correspondingly decreases. This observation is also true in the case of photocatalysed reactions. The temperature coefficient of the dark reaction between potassium

oxalate and halogens was found to be much higher than that of the corresponding photochemical reaction.

Photochemical action of tropical sunlight

Contrary to the observation of Lindemann, Dhar, Banerjee and Bhattacharya found that the hydrolysis of cane sugar is accelerated by tropical sunlight. Such powerful radiations were also effective in decomposing potassium nitrate and potassium chlorate (Dhar and Sanyal) and in bringing about reaction between sulphur dioxide and oxygen at ordinary temperature. Dhar and Atma Ram claim that solutions (5%) of bicarbonates of the alkali metals on exposure to sunlight for about 4 hours in thin layers in dishes covered with silica plates at temperatures not exceeding 30°C. gave formaldehyde as detected by Schryver's reagent. Qureshi working at the Osmania University could not confirm this observation. Another highly interesting observation of Dhar and Chakraborty is the detection of nicotine and amines on the exposure of dilute solutions of ammonia, formaldehyde, and cupric salts in presence of catalytic surfaces like ZnO, TiO_2, etc. to tropical sunlight for 80 hours. Potassium nitrate with glucose under similar conditions gave tests of arginine and with glycol gave glycine. Longer exposure causes the disappearance of the amino-acids due perhaps to photo-oxidation. Dhar and collaborators (Rao, Biswas, Bhattacherjee, Mukherjee, Tandon) have shown that tropical light plays an important part in the phenomenon of nitrogen fixation, nitrification and ammonification which are believed to be mainly oxidation reactions. They made numerous comparative experiments on the oxidation of ammonium salts to nitrite and of nitrite to nitrate with both sterilised and unsterilised soils kept in light and in the dark and found that the formation of nitrite and nitrate was always much greater in vessels exposed to light than in those kept in the dark. They also observed that amino-acids are readily oxidised to ammonia in air and light. The amount of the nitrate in Northern Indian soil was found to be maximum in summer, and as most of the bacteria are likely to be killed owing to the high temperature prevailing in the soil, it is concluded that light plays an important rôle in the nitrification in soils. The practice of increasing the fertility of soils by exposing fresh surfaces to sunlight thus finds a satisfactory explanation.

Photobromination

Intensive studies of many photochemical reactions have been made by J. C. Ghosh and collaborators at Dacca with a view to unravel the mechanism of such reactions. In the dark reaction between bromine and organic hydroxy acids, the reaction is initiated by active molecules of bromine and then propagated by chains where free bromine molecules are activated by collision with 'hot' molecules of reaction products. The chains are broken by Br_3-ion, and a satisfactory explanation has been put forward for the observation that with diminished chain-length, the bimolecular dark reaction

with respect to bromine degenerates into unimolecular reaction in presence of bromine ion. The corresponding photochemical reaction is, however, due to the formation of bromine atoms produced by photodissociation of bromine molecules, the mechanism of the subsequent chains being similar to that of the dark reaction. For complete absorption of incident radiation it necessarily follows that the photochemical reaction is unimolecular with respect to bromine and is zero molecular in the presence of bromine ion. In those cases of photobromination, however, where the reaction consists in the addition of two bromine atoms to an unsaturated molecule the chains are propagated by the formation of triatomic bromine molecules by the reaction of a bromine atom with a bromine molecule; the considerable influence of the acceptor molecule on the velocity of photobromination which was overlooked by Berthoud has also been explained (Ghosh and Purakayastha). A small induction period was observed which was followed by an after-effect when the source of illumination is withdrawn. This proves unmistakably that there must be some immediate complex formation. Berthoud's method of varying light intensity by the use of rotating sector is in this case open to an obvious objection. The temperature coefficient of these photochemical reactions, which is approximately 1·4 for 10° rise, has been ascribed to the energy of activation in the reaction $Br+Br_2 \rightarrow Br_3$, the activation energy of 11,000 cal being the energy difference between the 2^2p_2 and 2^2p_1 states of the bromine atom (Ghosh and Bhattacharyya).

Quantum yields as dependent on the wavelength of exciting radiation

Interesting results have been obtained indicating that quantum yields are generally the greater, the shorter the wavelength of the exciting monochromatic radiation. Thus in the reduction of ferric salts by lactic acid, the quantum yield dropped from unity to 0·4 when the wavelength diminished from 390$\mu\mu$ to 488$\mu\mu$. In the more complex photobromination of cinnamic acid, the chain-length diminished from 55 to 28 as the wavelength increased from 366 to 545$\mu\mu$ (Ghosh and Purakayastha). Similar dependence of quantum yields on the wavelength was observed in the photobromination of acetylenedichloride, and the interesting observation has been made that the chain-length of the reaction in the pure gaseous phase is much greater than in solutions of carbon tetrachloride, which indicates that even an inert solvent molecule whose dipole moment is zero can sometimes break the chains (Ghosh and Bhattacharyya). Studies of photochemical reactions under the simultaneous influence of two monochromatic radiations have revealed the fact that where the primary process consists in the photodissociation of the molecule, as in the case of bromine, the total effect of two simultaneous radiations is less than the sum of the individual effects. This is to be expected because the velocity of reaction in such cases is propor-

tional to the square root of the absorbed radiant energy (Ghosh and Bhattacharyya).

Photosensitizers

Dhar and Sanyal have shown that the bimolecular reaction between potassium oxalate and mercuric chloride becomes unimolecular in presence of light and the photochemical reaction is further accelerated by ferric, aluminium, nickel, cobalt and uranyl ions. In the near ultraviolet region, uranyl salts have been found generally to act as photocatalysts (Ghosh, Banerjee, Bhatta, Narayanmurti, Ray). For example, the dehydrogenation of succinnic acid and mandelic acid by methylene blue can be effected by a uranyl salt as a photocatalyst which thus simulates the action of dehydrogenase. Iodine has been found to act as a photocatalyst in the isomeric transformation of allocinnamilidine acetic acid into the normal form. In solvents of high dipole moments like alcohol, the excited iodine molecule acts as photosensitizer, and the velocity of reaction is proportional to the intensity of absorbed radiation. With increasing concentration of iodine, the velocity of reaction passes through a maximum which is also true of fluorescence capacity. In solutions of benzene and carbon tetrachloride, the mechanism of reaction is entirely different, iodine atoms derived from photodissociation acting as catalyst; contrary to general expectation it has been found that the quantum yield in the latter solvents diminishes as the wavelength of the exciting radiation diminishes (Ghosh, Mitra, Narayanmurti, Das Gupta). Dhar and collaborators are of opinion that the primary process in photochemical reactions with iodine need not be the photo-dissociation of the molecule, because radiations of wavelength which are incapable of dissociating an iodine molecule have been found to be active in photoiodination. Extensive studies on the photocatalytic activity of micro-heterogeneous systems have also been made (Ghosh, Banerjee, Nundy, Mukherjee). It has been shown that at *p*H below 7 a large number of organic substances like sugar, alcohol, and aldehyde can be oxidised by hydrogen peroxide with photosensitizers like tungstic acid sol, molybdic acid sol, vanadic acid sol, chromic tungstate sol, etc. The important observation has been made that if the sols are exposed to active radiations for several hours just before they are mixed with the other reagents to form the reaction-mixture, the long induction period generally observed in such cases disappears. When the concentration of hydrogen peroxide is not too small, the velocity of reaction is independent of the concentration of H_2O_2, and is proportional to the square root of the absorbed radiation ($366\mu\mu$). The influence of *p*H appears to be peculiar in that in many cases the velocity passes through a maximum with increasing *p*H. The photo-excited sols thus simulate the action of peroxidase.

Photochemical action of polarised light

Bhatnagar, Lal and Mathur have studied the action of polarised light on bacterial growth and animal metabolism and claim to have observed a differential effect. Bhatnagar and Anand also found differences in the velocities of reaction when polarised and unpolarised light are allowed to act upon surfaces of sodium and potassium amalgam under water. Ghosh and Kappanna, early in 1926, made a very careful study of the photodecomposition of potassium manganioxalate, which is a racemic mixture, by *d* and *l* circularly polarised light. The quantum efficiency was found to be unity, but no preferential decomposition of either of the optical isomers could be detected, as was later observed in the classical investigation of a similar reaction by Kuhn.

Chemiluminescence

The phenomenon of chemiluminescence has been studied by Bhatnagar, Dhar and their pupils. A large number of dyes dissolved in various solvents have been found to emit light when oxidised by ozonised oxygen.

Absorption spectra

Bhatnagar, Shrivastava, Mathur and Sharma have studied the Tesla-luminescence spectra of iodine and found that the fluorescence term in the band equation arises from emission of energy as the molecule returns from the higher excited state to the metastable $2p_1$ state. Ghosh and Sengupta have measured the extinction coefficients of chlorophyll α and chlorophyll β and their mixtures in acetone solution and their emulsions in water with the help of lecithin. Many plant physiologists are of opinion that the chlorophyll in plant leaves exists in a state of true solution in lipoid bodies which in their turn remain suspended in aqueous medium as fine colloidal particles. The general nature of the absorption curves did not vary, though the values of the extinction coefficients changed considerably. Considerable increase in the values of extinction coefficients has been observed when uranyl, ferric, mercuric and copper salts are mixed with organic substances containing hydroxyl or carbonyl groups and attempts have been made to explain the results quantitatively on the hypothesis of formation of molecular complexes (Ghosh, Mitra, Rangacharya, Chakravarti). These observations have been extended by Dhar and co-workers who find that there is always an increased absorption of radiation when substances capable of reaction are mixed together. The full implication of this generalisation has yet to be worked out.

Carbon Assimilation

Ghosh has given a quantitative form to the theory of Willstätter and Stoll regarding carbon assimilation by the photosynthetic activity of chlorophyll and has shown that his equation is in agreement with the data of Harder on photosynthesis by fontinalis and those of Warburg on photosynthesis by chlorella. He has also studied the mechanism of photochemical reduction of methyl red by

phenylhydrazine with chlorophyll as sensitiser. Dhar and Gopala Rao have observed that the amount of carbon monoxide obtained from carbon dioxide subjected to radiation from a 500 watt lamp is considerably greater in presence of chlorophyll than in its absence.

Photovoltaic cells

In agreement with the views of Perrin, Ghosh has postulated that under the influence of intense radiation, fluorescent molecules of electrolytes may undergo polymerisation by way of an intermediate unstable molecule and that a noble metal electrode dipped in such solutions indicates reversible E.M.F. due to possibility of electron transference by such intermediate unstable molecules. On this basis, he has developed the following equation for photovoltaic cells :—

$$E = 0{\cdot}056 \log_{10} [1 + k_1\sqrt{I} \tanh (tk_2\sqrt{I})]$$

where I is the intensity of radiation and t is the time. This equation has been found to give an exact quantitative interpretation of the accurate experimental data of Rule on the rate of development of E.M.F. in photovoltaic cells containing fluorescent electrolytes.

Chemical reaction under electric discharge

Important researches on this subject are now in progress in the laboratories of the Benares University under Professor Joshi, who has studied the decomposition of N_2O, NO, NO_2, SO_2, SO_3, PH_3, H_2O, H_2O_2, H_2S, benzene and paraffins, the interaction in H_2, O_2 and H_2, Cl_2 mixtures, deactivation of active nitrogen, latent image and ' corona pressure ' effects. It has been observed that when a change is producible ordinarily only at high temperatures, its products due to electronic and thermal activation are analogous. Materials which, however, decompose at low temperatures give very different products when produced electronically and thermally. Results with spark discharges resemble high temperature pyrolysis. Velocities of reaction were found to be markedly depressed by traces of impurities having large electron affinity. The occurrence of a chemical reaction under electric discharge is characterised by a minimum required voltage across the reaction space which may be called ' threshold potential '. The combination of chlorine with hydrogen under coronas in Siemen's tubes was studied in regard to the threshold potential under a wide variety of conditions. Oxygen and ammonia, which retard this photochemical reaction, also increase considerably the threshold potential. Studies of ionisation current during decomposition have given marked indications of intermediate stages, and the reaction mechanism is best visualised in terms of chains set up along the trajectories of the moving ions, the length of the chains being similar to that of photochemical reaction. It has been observed that the pressure of a gas subjected to discharge is in small excess over that indicated by the temperature of the system and that this excess is sensitive to applied fields.

A spectral shift indicative of deactivation occurs in the after glow of active nitrogen when exposed to the aerial effect from an intermittent and condensed spark discharge. Bhatnagar, Sharma and Mitra have also studied some chemical reactions under electrodeless discharge.

Electrochemistry, Ionic activity, Overvoltage

J. C. Ghosh has attempted to explain the properties of strong electrolytes on the hypothesis of complete dissociation, the ions however being subject to forces of coulomb attraction. The exact quantitative formulation of the hypothesis later on by Debye and collaborators form a landmark in the development of electrochemistry. Kappana has studied the velocity of ionic reactions from the standpoint of the concept of ion-activity, and Mukherjee has formulated the conditions which must be satisfied in order that a sharp boundary may be maintained in experiments designed for the measurement of transference numbers. Ghosh has observed that the hydrogen and oxygen overvoltage at noble metal electrodes can be considerably reduced by the superimposition of a high frequency alternating current from small induction coils, and in some cases the true decomposition potential can be measured with the aid of this device.

I. R. Rao has studied the Raman spectra of solutions of nitric acid and found 4 lines due to undissociated HNO_3 molecule, and 3 lines due to NO_3-ion; measurement of relative intensities at different concentrations led to the conclusion that the dissociation of nitric acid increases with diminishing concentration, but the degree of dissociation is much higher than that calculated from molecular conductivity. It is considered that Raman results gave the true degree of dissociation.

Colloid Chemistry : Emulsions

Very important studies on the properties of emulsions have been made by Bhatnagar. Using emulsions of pure aniline in water, where at 46°, gravity influences are eliminated by equal densities of the two liquids, Bhatnagar observed a close similarity between such emulsions and colloidal suspensions and observed that electrical factors outweigh the effect of interfacial tension in determining the stability. He found that the order of coagulating efficiency of ions is given by $Al > Cr > Ba > Sr > K > Na$. Investigation of volume relations in emulsions of olive oil in caustic potash solution indicated that the phase ratio at the inversion point increased from 74 : 26 in dilute alkalis to 89 : 11 in higher concentration and Bhatnagar concludes that this change is due to a gelatinous film enveloping the oil globules. Recognising that the presence of free alkali and free fatty acid makes the system more complex, Bhatnagar investigated the inversion of paraffin oil emulsions by various soaps and observed that the inverting capacity of the electrolytes follows the order $Al > Cr > Ni > Pb > Ba > Sr$. In all cases it was found that the amount of electrolyte

necessary to effect the reversal of phases increased as the volume of the aqueous phase was increased. Replacing soaps by insoluble suspensions of zinc hydroxide, lead oxide, casein, lecithin, rosin, etc. Bhatnagar concluded that all emulsifying agents having an excess of negative ions on them and wetted by water will yield oil-in water emulsions, while those having an excess of positive ions and wetted by oil will give water-in oil emulsions and enunciated the following rule :—An emulsion of water-in oil can be transformed into one of oil-in water by electrolytes having reactive anions like $O\bar{H}$ or $PO_4^{\equiv}$, and the reverse transformation is favoured by electrolytes having reactive cations like H^+, Al^{+++}, Th^{++++}, etc. In the course of his work, Bhatnagar has developed a neat method based on measurement of electrical conductance for determining accurately the inversion point of emulsions.

Electrochemistry of Colloids

In 1921–1922, J. N. Mukherjee developed a theory of double layer and of the electrical adsorption of ions in which the part played by the lattice forces in the adsorption of constituent ions by polar precipitates and in the origin of double layer was emphasised—a point of view later postulated by Fajans and developed by him and his co-workers in connection with their work on adsorption indicators.

In contrast with Gouy's theory of the diffuse double layer which keeps the manner of origin and distribution of charges in the double layer vague and open, Mukherjee postulated that the electrical double layer surrounding the colloidal particle should be considered to be composed of three parts: (1) the primarily adsorbed electrolytic ions held on the surface by lattice forces, (2) a secondarily adsorped layer which is also fixed on the surface, and (3) a diffuse layer consisting of mobile ions. Mukherjee's theory affords a simple explanation of the cation series (lyotrope) often met with in colloidal systems.

There is now a flourishing school of colloid chemistry in Prof. Mukherjee's laboratory at Calcutta, where research work has been conducted on the following subjects :—

(i) The coagulation of colloids.
(ii) Ionic antagonism.
(iii) The conditions to be satisfied for reliable measurements of cataphoretic speeds by the method of moving boundaries.
(iv) The variations of cataphoretic speeds (*a*) with the concentration of different electrolytes, (*b*) on the addition of non-electrolytes, and (*c*) during and after coagulation.
(v) The surface charge of polar precipitates and the variation of the charge on the addition of different electrolytes

and the relation of the charge to the adsorption of ions.

(vi) The surface charge and adsorption of ions by activated charcoal.

(vii) Development of an acid or alkaline reaction on the double decomposition of neutral salts of strong acids and strong bases and on the interaction of such salts with insoluble substances.

(viii) The electrochemical properties of colloidal solutions of pure inorganic substances and their characteristic properties which distinguish them from true solutions of electrolytes.

(ix) The measurement of the rate of migration of electrolytic ions under a known potential gradient and investigations on the concentration adjustments near the boundary of two electrolytes.

(x) The electrochemical properties of hydrogen clay.

The accurate method of measuring the cataphoretic speeds of colloidal solutions developed by Mukherjee, Chaudhury and others is based on a recognition of the Kohlrausch-Weber theory of ionic migrations and enables one to follow the potential changes at and near the boundary. The variations in cataphoretic speeds studied with the help of this method and the microcataphoretic method, show among other things that (*a*) coagulation rarely takes place at the isoelectric point, (*b*) it is not justifiable to speak of a critical potential characteristic of the coagulation stage, (*c*) the cataphoretic speed generally increases on aggregation, (*d*) there is a sudden drop in the speed in the final stages of aggregation, (*e*) the adsorption and desorption of ions can be followed in many cases from variations in the cataphoretic speed, and (*f*) non-electrolytes influence the cataphoretic speeds either by altering the adsorption of oppositely charged ions or by changing the dielectric constant of the double layer.

H. L. Ray, J. K. Basu and P. N. Kundu have shown that neutral polar precipitates purified with great care, e.g., silver halides, have a negative surface charge and adsorb very strongly its constituent ions. For ions which can form insoluble salts with one of the constituent ions, the order of adsorption does not always agree with the order of solubilities. These observations have been corroborated by later workers using other methods. During the double decomposition of barium chloride and potassium sulphate, an acid or alkaline reaction may develop and J. K. Basu has shown that the simultaneous measurement of surface charges afford a simple explanation of these observations on the basis of the absorption of ions.

S. P. Raichoudhury and also H. K. Acharya have carried out systematic investigations on the adsorptive properties of activated

charcoal and the relation of its surface charge to the absorption of acids and alkalis.

The interaction between neutral salts and such substances as silicic acid or manganese dioxide or copper oxide have been studied by B. N. Ghosh, K. Krishnamurti and others. Their results show that measurements of the surface charge are very helpful in understanding the nature of such reactions and that consideration of the adsorption of ions affords a more consistent explanation of the observations than that of solubilities.

B. N. Ghosh observed a parallelism between the effect of neutral salts on the electric charge of hydrated manganese oxide sol and the concentration of H^+ liberated. He has also studied the swelling, electric charge, and membrane potential of gelatin and albumin in relation to H^+ ion adsorption and the effect of proteins on the coagulation of bentonite suspensions by electrolytes.

During the past few years a considerable amount of work has been done by H. K. Sen, S. P. Raychaudhuri, B. R. Majumdar, R. P. Mitra, S. Mukherjee and B. Chatterjee on the electrochemical properties of colloidal solutions of silicic acid, palmitic acid, and hydrogen clays. These investigations deal with extremely low concentrations of free and total acidities. The results show that osmotically active hydrogen ions are associated with the colloidal particles and that such systems present features which cannot be reconciled with the assumption that they are single-phase systems, or with the deductions from classical electrochemistry. The total acidity is an ill defined variable quantity even when there is no evidence of a dissolution of the particles. Considerations of the phase rule are helpful only when fully formed phases are involved.

Cations have a marked effect on the total and free acidities, and a regular and specific cation effect has been distinguished. The regular cation effect agrees with the lyotropic series. The salt molecules at the surface are partly in solution and are partly insoluble and considerations of the energy of formation of ion pairs formed by adsorption are more suitable than those of solubilities in understanding the thermodynamic equilibrium. An attempt has been made to bring the similarities and dissimilarities of the properties of acids in true solution and those in colloidal solution into a general picture. These researches are of considerable importance in relation to the properties of hydrogen clay and the soil adsorption complex.

Kinetics of Coagulation

Mukherjee and co-workers have studied the influence of dilution on the coagulation of suspensions, and also the kinetics of slow coagulation with special reference to Smoluchowski's well-known equations. This problem is also being exhaustively studied by Joshi and co-workers who have employed different properties for following the progress of the change : surface tension, viscosity,

transparency, opacity and refractivity. The results showed that (i) the view generally held that coagulation necessarily leads to rise in viscosity is unjustified ; in fact, definite cases of well-marked coagulations were observed in which viscosity showed a marked over-all diminution ; (ii) usually, though not invariably, a moderately *slow* coagulation shows a small initial diminution of viscosity, followed by subsequent increase ; and (iii) the progress of a *slow* coagulation as recorded by viscosity change is not *time-continuous*, but characterised by *zones*. Besides viscosity, opacity has had the longest and widest usage in coagulation measurements. Joshi's results have shown that a change in none of these properties can be employed as a *general* quantitative measure of the corresponding degree of coagulation. For example, in numerous coagulations of colloidal arsenious and antimony sulphide by various concentrations of aqueous $HgCl_2$, the above properties were observed to be sensibly stationary, while flocculation was being produced in the system. Using colloidal MnO_2 and Hg_2SO_4 and other electrolytes the opacity *decreased* during coagulation. Furthermore, measurements have been made of the refractivity, viscosity and opacity in sols before and after '*thermoageing*', which is allied to coagulation, and changes in the last two properties were observed to lie in some well marked cases in the *opposite* sense ; independently of whether 'thermo-ageing' is akin to coagulation or its reverse, the above finding disturbs the present almost axiomatic view that coagulation should produce a rise in either of these properties. Confirmation of the above conclusion from viscosity determinations was also obtained by transparency measurements, in the electrolytic coagulations of colloidal As_2S_3. The existing theories of the mechanism of coagulation have assumed tacitly that it is *time continuous*, but Joshi's measurements have been of conspicuous utility in revealing a *zonal effect* as a general feature in numerous *slow* coagulations employing different sols and coagulants.

Based, in part, on an extension of the Freundlich's isotherm so as to include the electrical factors distinctive of the micellar adsorption of the coagulating electrolyte, a *general* theory has been developed for the kinetics of coagulation, which leads to the following equation for the rate of coagulation :

$$\frac{dx}{dt} = mac^{\epsilon/n}\cdot\left[1-\left(\frac{\Delta c}{c}\right)^{\epsilon/n}\right],$$

where the various symbols have their familiar significance. This equation yields *as a particular case* of Smoluchowski's well-known expression for rapid coagulation and the independence of $\frac{dx}{dt}$ of C, the concentration of the coagulating electrolyte.

The existence of a hitherto unrecognised determinant of the coagulation process was the finding that the characteristic auto-

coagulability of colloidal MnO_2 was increased considerably by addition of but small amounts of such substances as filter and parchment paper, celluloid, animal charcoal, unglazed porcelain, all carefully cleaned before introduction in the sol. The rate of coagulation *increases* markedly by introducing the wall material in a divided form. The magnitude of the well effect depends upon the nature of the coagulating system. Paraffinning the walls of the containers not only depresses the coagulation rate but induces *autocatalysis*, as judged by the familiar *S*-shape, and the rise in β, the Smoluchowski's coefficient of coagulation. The induction of autocatalysis (besides a diminution of the rate) on paraffinning the containing walls shows that this effect cannot be considered as fundamental to coagulation as has been supposed by some workers. That it is chiefly a secondary factor which adds on to the main change is shown by the result that some apparently autocatalytic coagulations ceased to be so, on simply introducing the wall material in a divided form in the coagulating system. The coagulation was then found to belong to either the *rapid* region when it satisfied the criteria for such a change in terms of Smoluchowski's classical theory; or else, it was classifiable as *slow* for which the above theory fails.

Extensive studies have also been made by Dhar and his collaborators, Chatterjee, Sen, Ghosh, Ganguli, Satyaprakas and Mehrotra on the problems of coagulation, hydration and gelation of colloids. It is difficult to do justice to this work in a short review, and only the major conclusions of interest will be stated. They conclude that the Schulze-Hardy Law is applicable only to that stage of coagulation when the charge of the colloid particle is being neutralised by the adsorption of an ion of the opposite charge; apparent deviations from this law are due to the existence of a second stage in coagulation—the further adsorption of electrolytes by the coagulum. They have also discussed the minimum concentration of electrolytes required for charge reversal and the dependence of the latter on the chemical affinity between the adsorbent and the substance adsorbed. Bhatnagar has made the interesting observation that the rotatory powers of sugars in presence of absorbing colloids are always less than those calculated from Beer's Law indicating that the adsorbed sugar loses its optical activity which supports the chemical affinity theory of protective action.

Periodic precipitation

Dhar and co-workers have studied in detail the phenomenon of periodic precipitation and the formation of Leisegang rings. Conductivity and diffusion experiments show that silver chromate in gelatin is present as a colloid and not as supersaturated solution. Periodic precipitations are formed by the coagulation of a peptised sol, and the coagulated masses in course of formation and also after precipitation absorb and coagulate the sol of the same material

in the neighbouring layer. Dhar and Chatterjee have made the interesting observation that in the formation of Leisegang rings of mercuric iodide, lead iodide; etc. in gelatin, agar and starch, the number of rings produced in light is much greater than in the dark. D. N. Ghosh has obtained periodic precipitates of sparingly soluble substances in the absence of a gel by placing drops of the reacting solutions on a glass plate, separating the drops by a fine paraffin line and finally covering with another glass plate so that the two surfaces of the drops were caused to meet.

Dhar, Mrs. Dhar, Pannalal and Ganguli have observed that some colloids become less stable towards electrolytes on exposure to light.

Scattering of light by Colloids

B. N. Ghosh has studied the scattering of light by stannic acid sols, and Krishnamurti studied the scattering of light in gelatin solutions. The latter has shown that when gelatin sols of various concentrations are cooled to 10°C., the depolarization of scattered light first decreases and then increases, the effect being pronounced in dilute solution and has drawn important conclusions regarding the change in shape and size of micelle.

Gel-formation and properties of Gels

The mechanism of the formation of several inorganic and organic gels has been investigated by Mata Prasad and co-workers. By the proper control of the H^+ ion concentration in the gel-forming mixtures many transparent inorganic gels have been prepared for the first time. Viscosity measurements have been made of colloidal systems undergoing gelation by means of Scarpa's method with certain modifications, the general conclusion being that gel-formation is a continuous process, that thixotropic gels like thorium molybdate show numerous irregularities, and that viscosity results can be expressed by the equations $\eta_s - \eta_0 = ae^{kt}$ and $\eta_s - \eta_0 = bt^c$.

Surface Tension

Bhatnagar has studied the solubilities of bi- and trivalent salts of higher fatty acids in oils and their effect on the surface tension of such oils. The conductivity and surface tension of univalent salts of higher fatty acids in the molten state have been measured (Bhatnagar, Mata Prasad and Balwant Singh). Interesting studies have also been made on the electrical resistance of thin films of organic liquids on papers and the relation between the chemical constitution of organic liquids and the transluscence of papers dipped in them (Bhatnagar, Mata Prasad, B. Ahmad, Mitra and Shrivastava). The concept of parachor has been applied to the examination of surface tension data of some organic substance in the molten state and of aromatic disulphides (Bhatnagar and Singh). Ghosh, Nath and Dutt have studied the variation with time of surface tension of solutions consisting of multimolecular aggregates having small velocities of diffusion, and have drawn important conclusions regarding the kinetics of formation of surface films.

Magneto-chemistry

The physical aspects of this subject are dealt with in another section. The important researches of D. M. Bose, Bhatnagar and P. R. Ray will be considered here from the physico-chemical point of view. It has been found that allotropic forms of sulphur differ considerably from one another in magnetic properties, but colloidal bismuth, after it has been thoroughly washed with hot tartaric acid solution which dissolves the oxides of bismuth, has practically the same diamagnetic susceptibility as regulus bismuth. In the case of electronic isomers, the empirical equation

$$\chi_M = -\frac{e^2 N}{6mc^2} \cdot K[\gamma^2]$$

gave values of K which are practically identical (Bhatnagar and Mathur). The diamagnetic susceptibilities of organic isomers differ in general from each other in the order ortho $>$para $>$meta, normal$<$ iso and the cis $>$trans variety (Bhatnagar, Mathur and Neogi). The susceptibilities of water and aliphatic alcohols were found to increase with temperature due probably to change in the degree of molecular association. The Paramagnetic ions Fe, Ni, Co, Mn exhibited diamagnetism when absorbed by charcoal (Bhatnagar, Mathur and Kapur). Optical rotation of solutions of active substances has been studied in magnetic fields and it has been observed that for any particular solvent, the field required to balance optical rotation is proportional to the optical rotation itself, and that in concentrated solutions, the magnetic rotation changes with concentration (Bhatnagar, Mathur and Jain). A large number of critical experiments on chemical reactions within and without the magnetic field led to the following conclusions :—In homogeneous reactions, the velocity is accelerated, retarded, or unaffected by the field when the sum of the molecular susceptibilities of the final products is greater, or less than or equal to the sum of the molecular susceptibilities of the initial substances. In the case of heterogeneous reactions, the solution of ferromagnetic iron in hydrochloric acid is retarded, while that of diamagnetic zinc is accelerated by magnetic fields (Bhatnagar, Mathur and Kapur). D. M. Bose finds that the magnetic moments of complex salts expressed in terms of Bohr Magnetons 'n' are mostly proportional to the difference between their 'effective' atomic number Z' and the atomic number of the next higher inert gas. Bose has shown $Z' = N - E + 2P$ where N = atomic number of the co-ordinating atom, E = its primary valency in the given compound and $P = 4$, 6, etc. according as the compound is fourfold, sixfold, etc. He finds that $n = Z - Z'$ where Z is the atomic number of the next rare gas and has gathered together a large amount of experimental evidence in support of his view.

Magnetic susceptibilities of a large number of complex compounds have been measured and the results show that the

Welo-Bose's rule is untenable in some cases (P. Ray and H. Bhar). A new view regarding the electronic constitution of molecular and complex compounds has been suggested (P. Ray). The constitution of isomeric compounds of dimethylglyoxime with cobaltous chloride has been reviewed as a result of the study of their magnetic susceptibilities (P. Ray and D. C. Sen). Magnetic susceptibilities of some simple cobaltic salts have been determined, and the electronic configuration of the cobaltic ion has been discussed (P. Ray and D. C. Sen).

Researches by Prof. H. E. Watson and Collaborators

Under the able leadership of Dr. H. E. Watson, a flourishing school of general chemistry grew up at Bangalore. Their studies included the cathode fall and spectra of rare gases and were followed by very accurate and painstaking investigation involving new technique and manipulative skill, on the atomic weights, compressibilities, refractive indices and dielectric constants of rare gases of the atmosphere. The work of revision of atomic weights was extended to antimony and tantalum. The measurement of dielectric constants, refractive indices and compressibilities of several other gases and vapours and the study of the influence of solvents on the dipole moment have formed subjects of more recent investigations.

A large number of early researches were directed to the study of kinetics of reactions in solutions, such as, esterification, hydrolysis, alcoholysis and acidolysis. Subsequent papers deal with the heterogeneous reactions, such as, oxidation, reduction and dehydration on the surface of metals, oxides and salts, and the application of thermodynamics to the equilibria involved in these reactions.

Photochemical studies include oxidation of toluene and benzaldehyde, phototropy of mercury compounds and photoelectric and photovoltaic phenomena, Budde effect of halogens, quantum efficiency of cis-trans conversion of cinnamic acids. Under this heading, mention should be made of the valuable contribution on the nature of reactions in electrodeless discharge, and on hot filaments (Srikanta).

Study of optical properties of organic compounds, such as Raman Spectra of isomeric compounds, absorption spectra and rotatory dispersion of isomeric terpenes and the relation between iodine value and refractive index, formed important part of more recent studies. Thin films of metals were examined by X-Rays.

Under Electro-chemistry mention may be made of the papers on the electrode potentials of metal—metal oxide electrodes, *p*H control of industrial processes, conductivity in mixed solvents, electroplating and electrotyping.

III. Inorganic Chemistry.

Researches in Inorganic Chemistry are being actively pursued in the laboratories of the University College of Science, Calcutta,

by Sir P. C. Ray, P. Ray and P. B. Sarkar, in the Government College, Lahore by H. B. Dunnicliff, in the Patna College of Science by R. C. Ray and in the Institutes of Science at Bangalore and Bombay. A brief outline of the work is given below :—

In continuation of his previous work on nitrites, the conductivity of nitrites of metal and alkyl ammoniums have been measured by P. C. Ray and Dhar. The mercury mercaptide nitrites have been prepared and their reaction with alkyl iodides studied (P. C. Ray and P. C. Guha). Compounds of mercuric nitrite with various alkaloids have been described (P. C. Ray). The velocity of decomposition and the dissociation constant of nitrous acid have been determined, and it has been found that urea reacts very slowly with pure nitrous acid—a fact which has been utilized by Werner in giving a new constitution of urea (Ray, Dey and J. C. Ghosh). Guanidinium nitrite has been prepared and its decomposition by heat studied (P. C. Ray, M. L. Dey and S. C. Jana).

Molecular volumes of the hyponitrites of alkalies and alkaline earths and equivalent conductivities of sodium hyponitrite, calcium hyponitrite and hyponitrous acid have been measured (P. C. Ray, N. R. Dhar, R. L. Dey). Vapour density of ammonium nitrate, benzoate and acetate have been measured (P. C. Ray and S. C. Jana).

Interaction of mercuric and cupric chlorides respectively on mercaptans and potential mercaptans has been studied (P. C. Ray).

Varying valency of gold (bi, ter, quadri and quinque) with respect to mercaptanic radicles has been studied (P. C. Ray and K. Bose-Ray).

A number of complex compounds of iridium with organic sulphides have been described (P. C. Ray and N. Adhikary ; N. N. Ghosh).

The action of mercuric, cupric and platinic chlorides on organic sulphur compounds has been studied (P. C. Ray).

A number of complexes of zinc and cadmium, and mercuric iodides with alkyl sulphonium iodides, as well as of antimony halides with alkyl sulphonium iodides have been prepared (P. C. Ray, N. Adhikary, S. K. Banerjee and N. Ray).

Double sulphates of copper-magnesium group and the sulphonium and phosphonium bases have been prepared and studied (P. C. Ray and N. Ray).

A number of compounds of gold chloride with organic sulphides have been described (P. C. Ray and D. C. Sen).

Fluorination of certain organic compounds has been effected by means of thallous fluoride (P. C. Ray, A. C. Ray and H. Goswami).

During the period under review, P. Ray and his co-workers have published a large number of papers on :

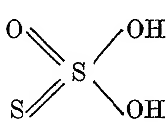
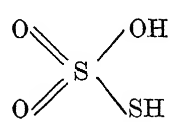
(i) Co-ordination compounds and co-ordination valency.
(ii) Macro- and micro-analytical methods.

From a study of the distribution of bromine and iodine between HCl and HBr solutions and various organic solvents the formation of HClBr, HClI and HBrI in aqueous solutions has been established (P. Ray and P. B. Sarkar). The latter substance has subsequently been obtained in the solid state mixed with ice (S. Roy).

A series of complex iodates of quadrivalent tin, titanium and lead of the formula $R_2[M(IO_3)_6]$—where R = H or any alkali metal and M = Sn, Ti or Pb—have been prepared and their molecular volumes compared (P. Ray, S. N. Ray and H. Saha).

A new series of acido-pentammine cobaltic salts, thiosulphato-pentammine cobaltic complexes—has been prepared. The general formula is represented by $[S_2O_3 . Co . (NH_3)_5]$ X, where X = halogens, NO_3, 1/2 CrO_4, 1/2 S_2O_3, or 1/2 S_2O_6. The bivalent thiosulphate radicle occupies one co-ordination position inside the complex and is, therefore, unicovalent ; its linking with the central atom occurs through an oxygen atom (P. Ray).

By the action of potassium cyanide upon thiosulphato-pentammine cobaltic chloride, the same author has prepared a new series of substituted cyano-cobaltiates,—$R_4[S_2O_3 . Co . (CN)_5]$ where R = any alkali metal atom or its equivalent alkaline earth metal,—in the form of bright yellow crystals (P. Ray ; P. Ray and S. N. Maulik). By the action of hydrogen sulphide upon the lead salt, the free acid, $H_4[S_2O_3 . Co . (CN)_5]$, has been obtained in two different modifications, one yellow and the other red. These hydrolyse giving rise to two different modifications of thiosulphuric acid, one decomposing into sulphur dioxide and sulphur as usual, and the other into H_2S and SO_3. This is regarded as a justification for the assumption that thiosulphuric acid may exist in two different isomeric forms :

 and 

(P. Ray and S. N. Maulik).

By the oxidation of the thiosulphato-pentacyano potassium cobaltiate with H_2O_2 in neutral solution buffered by sodium acetate, a series of aquo-pentacyano cobaltiates—$R_2(H_2O) . Co . (CN)_5$, where R = alkali or the equivalent alkaline earth metal—has been prepared (P. Ray and N. K. Dutt).

By the action of potassium cyanide upon a cold solution of cobalt chloride saturated with SO_2, another substituted cyano-cobaltiate of bright orange colour, $K_6(CN)_5 . Co-SO_3-Co . (CN)_5$ μ-sulphito-decacyano hexapotassium dicobaltiate, has been prepared (P. Ray).

By substituting sodium cyanide for potassium cyanide in the above preparation, a series of disubstituted cyano-cobaltiate,

$R_5[(SO_3)_2 . Co . (CN)_4]$ disulphito-tetracyano cobaltiate, where R = alkali or equivalent alkaline earth metals or other heavy metals, has been obtained in the form of bright yellow crystals (P. Ray and S. C. Chakraborty).

A corresponding series of diaquo-tetracyanocobaltiate, of the formula $R[(H_2O)_2 . Co . (CN)_4]$ has been obtained by the oxidation of the above disulphito-tetracyanocobaltiate with strong nitric acid and subsequent hydrolysis. The free acid of the series, prepared from the lead salt, when heated, gives a blue cobaltic cyanide $Co(CN)_3$. This latter, on treatment with water, gives a red hydrated modification, $Co(CN)_3 . 2H_2O$ (P. Ray and T. Gupta Chaudhury).

By oxidizing with air a solution of cobalt chloride mixed with ethylene diamine, followed by treatment with sodium thiosulphate, dark greenish black crystals of trans-dithiosulphato-diethylenediamine cobaltiate have been obtained. The isomeric cis-modification is prepared from the latter by treatment with caustic alkali (P. Ray and S. N. Maulik).

Rubeanic acid has been employed as a very sensitive reagent for the micro-detection of copper, cobalt and nickel, as well as for the macro-estimation of cobalt and nickel (P. Ray, R. M. Ray). This reagent is now sold in the market.

Hexamethylene tetramine has been employed as a useful reagent for the quantitative separation of iron, titanium, and uranium from zinc, manganese, nickel, cobalt, alkaline earths and magnesium. Aluminium has also been separated from the latter metals by the same reagent except in the case of nickel and zinc (P. Ray, A. K. Chattopadhya and D. Bhaduri). This reagent has also been employed for the microchemical detection of several metallic ions (P. Ray and P. B. Sarkar).

Quinaldinic acid has been introduced as an analytical reagent for the estimation of copper and its separation from almost all other elements excepting zinc in mineral acid solution. Zinc has also been estimated by the same reagent with excellent results in the presence of phosphoric acid, arsenic acid, iron, aluminium, titanium, uranium, beryllium, manganese, magnesium, and the alkaline earth metals in acetic acid solution. The same reagent has further been used for the micro-estimation of copper and zinc and for the colorimetric estimation of iron (P. Ray, M. K. Bose, A. K. Mazumdar and J. Gupta).

Dimercapto-thiobiazole has been employed as an analytical reagent for the separation of copper from As, Sb, Sn, Mo, W, Fe, Zn, all metals of group III (analytical) and succeeding groups. The same reagent serves to separate lead from As, Sb, Sn, Mo and alkaline earths. (P. Ray and J. Gupta).

P. B. Sarkar has prepared a large number of inorganic and organic salts of scandium, gadolinium and europium and an attempt

has been made to determine the analogies which exist between the compounds of these elements and those of other tervalent elements. Thus scandium acetyl-acetonate and salts of the types M_3ScF_6 and $K_3[M(C_2O_4)_3]5H_2O$ strongly resemble those of the tervalent elements of the iron family.

Some new complex salts, such as, transtetrammine-aquo-thiosulphato-cobaltic salts ; chromiselenic acid, chromi seleno mono-, di-and tri sulphuric acids and their salts ; chromato cobaltammine and cobaltammini chromates ; and two trinuclear chromium compounds have been described (P. B. Sarkar). Thiocyanates of Cd, Zn, Co, Ni and Mn have been found to give sparingly soluble salts with N_2H_4, having the formula $M''(SCN)_2, 2N_2H_4$; and Ni, Co and Cd have been estimated by precipitating with NH_4SCN and N_2H_4 (P. B. Sarkar). Manganese has been accurately determined by $KMnO_4$ in the presence of $MgSO_4$, KNO_3, K_2SO_4, $CdSO_4$, $NaNO_3$, KI, Na-Ac and chlorides of Li, Na, Ca, Ba, Sr. Some of these salts form manganites and others coagulate the precipitate (P. B. Sarkar). Sarkar and Goswami have prepared triple nitrites of the following composition :—

$Cs_2NaR(NO_2)_6$ where R=Ce, La, Pr, Nd, Sm or Gd. These triple nitrites may be used for the micro-detection of Cs limit of sensitiveness being $0{\cdot}04\gamma$. Sarkar and Ray have made an interesting study of the homology of BeF_4^- and $SO_4^=$ and monofluo-phosphate ions from chemical, structural and crystallographic points of view. Starting from the idea that fluocarbonate ion, if it could be prepared, should be analogous to nitrate ion, Sarkar has succeeded in preparing fluocarbonic esters and has developed a new method of fluorination by Tl.F. Mixed crystal formation of formates with nitrites led Sarkar to some interesting suggestions regarding the constitution of formate ion and formic acid. An exhaustive study of the Raman spectra of these compounds has been made to test these new ideas.

R. C. Ray has shown that the so-called amorphous boron prepared by the reduction of boron trioxide with Mg probably consists of a soild solution of a lower oxide of boron, sometimes in combination with a little MgO in elementary boron. Later on, by extracting the fusion with water, a new salt, magnesium borite, MgO, B_4O_5 has been discovered in the solution. The constitutional formula of the corresponding acid is considered to be BO.(OH) : BO. BO : BO(OH). When Mg_3B_2 is treated with water, hydrogen is evolved and an insoluble compound of magnesium oxide with a boro hydrate is formed. The borohydrate is represented by the formula $H_4B_2(OH)_2$. With dilute acid, Mg_3B_2 gives at or below 0°C. a larger volume of hydrogen and an insoluble salt $Mg_3B_2(OH)_6$ while below −10°C. a different product $H_3B_2Mg(OH)_3$ is formed. Banerjee has prepared some new mercury-ammonia compounds (1) such as NH_2HgCl, $HgCl_2$, $2NH_3$; NHg_2SCN ; $[NH_2Hg_2O]$, AsO_4, $3H_2O$ $[NH_2Hg_2O]$ CrO_4.

He has also used divalent vanadium sulphate as an analytical reagent for the volumetric estimation of copper, iron, chromium, nitrate, chlorate and persulphate.

The publications from Prof. Dunnicliff's Laboratory include studies on the basic carbonate of copper, the hydrogen sulphates of alkali metals and ammonium, the action of bromine on strontium oxide and its hydrates, and the action of hydrogen sulphide on nitric oxide, on solutions of nitric acid, chromic acid, chromates and dichromates. Conditions of equilibrium have been investigated in the following systems :—

Sodium sulphate, sulphuric acid and ethyl alcohol,
Ammonium sulphate ,, ,, ,, ,, ,,
Potassium sulphate, cadmium sulphate and water
Ammonium sulphate ,, ,, ,, ,,

At the Indian Institute of Science, extensive investigations of the reactions of chromates and sulphates at high temperature have been made and have proved to be of considerable technical importance. In particular, the study of the decomposition of chromates of alkaline earths at high temperatures and in vacuum led to the discovery of intermediate compounds of chromates and chromites.

Research in Inorganic Chemistry at the Osmania University was mainly carried out on the constitution of per- and double compounds and the electrodeposition of metals. Titanium peroxide was found to be a true peroxide and a formula of TiO_3, $1{\cdot}5H_2O$ was assigned to it. A double compound of $SnCl_4 . 4CH_3COOH$ was prepared and isolated. The so-called percarbonates of Wolffenstein and Peltner were found to be mixtures of Na_2CO_3 and $NaHCO_3$. The formula of Tanatar's compound Na_2CO_3, H_2O_2, $2H_2O$ was confirmed.

Studies in the Royal Institute of Science, Bombay, on the physical and chemical properties of nickelous oxide prepared by heating its salts to high temperatures indicated that the solubility of the oxide in sulphuric acid diminishes remarkably as the temperature of preparation is raised and at about 1000° almost passive oxide is obtained. On these observations the mechanism of reactions taking place in the Mond's process has been explained.

The electrical conductivity and the H^+ ion concentration of solutions of amphoteric oxides in sodium hydroxide have been measured by Mehta who concluded that in dilute solutions these oxides are present as colloids but in concentrated solutions they contain salts with a small amount of the oxide in the colloidal state. Crystalline sodium zincate, Na_2ZnO_2, $3H_2O$, has been isolated. Mehta has also studied the decomposition of sulphates of alkaline earths between 900°–1100° in the presence of boric anhydride. 95% of $CaSO_4$ is decomposed at about 1000° and this temperature is lowered by the addition of suitable substances to the furnace charge.

Very few chemists in India have worked on rare metals. P. Neogi and Nandi, have recently been working on gallium and have prepared numerous compounds of this rare metal including a di-hydrate, chlorate, bromate, basic iodate, oxalate, acetate, *d*-, *l*-, meso- *r*- tartarates and citrate. Neogi and co-workers have also studied the mechanism of the reaction between (1) sodium bicarbonate and mercuric chloride, (2) hypophosphorous acid and copper salts, (3) hypophosphorous acid and sodium iodate, and have determined the effect of concentration, temperature, etc. on the period of induction observed in the reactions.

IV. Organic Chemistry.

Four broad lines may clearly be discerned along which the largest volume of research has been carried out. Of these, again the most consistently and usefully prolific line has, in the opinion of the reviewer, been the isolation, characterization, constitution, determination, and synthesis of a large variety of terpenes and terpene-derivatives. The second broad line has traversed the extensive region of synthetic dyestuffs of the more common, and in some cases, unfamiliar types, and some attempts have been made to elucidate the relation between the colour in these compounds with their molecular structure.

The third line has included the study of a large number and variety of natural products other than terpenes and much analytical and exploratory research has been spent on: (*a*) vegetable and animal oils and fats, (*b*) bitter principles and glucosides, (*c*) plant-colouring matters, and (*d*) alkaloids, etc.

There is a greater tendency in recent years among chemists to undertake this kind of work and much useful data on the chemical and pharmacological properties of the active principles of indigenous plants may be expected in the near future.

The fourth broad line has embraced the syntheses and chemical study of a very wide variety of heterocyclic compounds of O, N and S. Though this line has been very vigorously pursued by Indian chemists, it is only in recent times that this type of work has received a new orientation, and attempts are now being made in several laboratories to prepare pharmacologically valuable synthetic products. It is hoped that the wide experience gained in the past in the synthetic side will prove helpful in producing useful results in the newer field.

On the whole, it may be said that the trend of modern research is more and more in the direction of producing or isolating substances: (*a*) which may have practical commercial or pharmaceutical value, (*b*) which may prove useful as synthetic intermediates or degradation products of more complex natural substances, or (*c*) which may help indirectly in elucidating the constitution of such complex substances.

Natural products related to the Terpenes

Valuable research was carried out at Madras and Bangalore by J. L. Simonsen aided by a number of Indian co-workers and in a few cases by J. J. Sudborough and E. R. Watson. The first important research undertaken was on the constitution of santalin, the red colouring matter of Sandal wood (1912). Various derivatives of this were prepared and their oxidations studied. Some of the oxidation products were independently synthesized from known benzene derivatives. During the period between 1912–28 a large number of terpenes (open-chain, mono-, di- and tricyclic, and sesque-) were isolated from a variety of Indian sources and carefully characterized. The constitution of several of them were elucidated. The following may be mentioned: myrcene, *d*-α phellandrene, Δ^3 and Δ^4 carenes, *d*-piperitol, *d*-piperitone, *l*-carvomenthene, *d*-α thujene, *l*-sabinene, zinziberine, curcumene and longifolene. The constitution of *d*-α phellandrene was established from its oxidation to isopropyl succinic acid; of α-terpinene by the production of 1 : 4 cineolic acid. The fact that sylvestrene does not exist in the plant, but is a product of transformation of Δ^3 or Δ^4 carene was established. The relation between γ-terpinene and Δ^4 carene was made clear. *d*-piperitone was oxidized to α-acetyl-isopropyl-butyric acid. Light was thrown on the constitution of thujene. Δ^3 carene was oxidized by Beckmann mixture to terpenylic and terebic acids. Much light was thrown on the constitution of Δ^4 carene and of carone. Norpinic acid was prepared. The sesqui-terpenes, zinziberene, curcumene and longifolene, and many of their derivatives and properties were studied.

Thujane

This work has been taken up again by P. C. Guha and co-workers who have synthesized it starting from dibromomenthone *via* 3-methyl-6-isopropyl-bicyclo-(0 : 1 : 3)-hexanone. Northujane-2 : 6-dicarboxylic ester has been synthesized by effecting direct bridge formation in ethyl cyclohexanone-2 : 6-dicarboxylate.

Carane series.—The synthesis of the following, the first three being degradation products of naturally occurring members of the carane group, has been effected: *caronic acid, homocaronic acid* and 1 : 1-*dimethyl-cyclopropane*-2 : 3-*diacetic acid* by the action of dimethyl-diazomethane upon fumaric, glutaconic and $\beta\gamma$-dihydromuconic acids respectively; and 2 : 2-*dimethylcycloheptane*-1 : 3-*dicarboxylic acid* from the product of reaction between Guareschi imide and tetramethylene bromide.

Pinane series.—The synthesis of '*keto-nopinone*' (4 : 6-diketo-nopinane), the first total synthesis in this group, has been achieved by cyclizing the methyl ester of pinononic acid (a degradation product of verbenone) synthesized in this laboratory starting from *cis*-norpinic anhydride.

Diethyl *cis-* or *trans*-norpinate gave on reduction the corresponding trans-glycol from which sym. *homo-pinic acid* has been synthesized, which could not be cyclized due to its trans-configuration. Pinic acid obtained from pinene and supposed hitherto to be *cis* has been shown to be of the *trans* form. *Norpinic acid* has been synthesized.

Camphane series.—1-*acetylcyclopentane*-3-*carboxylic acid* (obtained by Semmler as a degradation product of santene), *keto-homonorcamphor* and *isodehydroapocamphoric acid* (by the action of dimethyldiazomethane on muconic acid) have been synthesized.

Starting from ethyl-*cyclo*hexane-1 : 1-dimethyl-3 : 5-diketo-2 : 6-dicarboxylate, a new bridged ketone $C_8H_{10}O$ has been obtained, which affords an interesting example of direct bridge formation indicating the presence of *p*-bonds in phenols.

Bicyclo-(2 : 2 : 2)-*octane* and *bicyclo*-(3 : 2 : 2)-*nonane* rings have been synthesized by bridging ethyl succinosuccinate in 1 : 4-positions by ethylene and trimethylene.

Presumably the Simonsen school has also inspired J. C. Bardhan, who has successfully laid at rest the vexed problem of the constitution of Balbiano's acid and has prepared some analogues of this compound. He has also thrown much light on the constitution of caryophyllenic acid. A recent extension of the experience gained in the terpene group has resulted in very elegant syntheses in the phenanthrene, hydrophenanthrene, retene and oestrin groups; also in the synthesis of bi-cyclo-octane and cadinene. As a side-line of this research S. C. Sen Gupta has studied the preparation and properties of 5- and 6-membered *spiro* hydrocarbons containing the tetrahydro-naphthalene and hydrophenanthrene skeletons, which are convertible into phenanthrene and anthracene and conjugated phenanthrene derivatives. Another series of investigations are being carried out by N. Chatterjee with the object of synthesizing the oxy-phenanthrene oestrin skeletons from unsymmetrical diphenyl derivatives and from other sources. This subject is receiving active attention in Calcutta.

Synthetic Dye-stuffs

The second broad line was inaugurated under the able guidance of E. R. Watson whose work in connection with the relation between colour and chemical constitution is now a matter of text-book knowledge. A. C. Sirker, an able co-worker of Watson, in 1916 suggested a modification of Hewitt's Rule for the azo-dyes where the depth of colour was found to be proportional to the length of the conjugated chain in the part of the molecule containing the auxochrome. Sarker and S. B. Dutta have continued their researches in this group vigorously for several years, jointly and severally. Dutta prepared a series of fluorescein-like dyes from diphenic anhydride and some azine and flavinduline dyes from phenanthraquinone. He also studied a number of pyronine dyes from substituted succinic and glutaric acids and put forward a

theory indicating the importance of ring-chain tautomerism in the development of the colour and the relation between colour and molecular strain. Another active group of workers in this field was (the late) R. N. Sen and his pupils at Calcutta who prepared and studied a number of dyes of pyronine, benzein, triphenyl methane and azo-dyes; also some colouring matters containing the tetra-phenyl-methane skeleton and others, where no quinonoid structure can be given to the molecule. A. C. Sirker and his pupils have prepared a number of azine, oxazole, iminazole, flavinduline, azo-methine, phenazine and azo-dyes from various ring ketones like phenanthraquinone, acenaphthenequinone, fluorenone, etc. A large class of indigoid, indazine and azine dyes have been prepared by P. C. Dutta and S. K. Guha.

Natural products other than Terpenes

In this broad group a large number of fatty oils from a wide variety of sources have been examined in detail in various laboratories mainly by Watson, Sudborough, B. S. Rao, T. Katti, S. Krishan, S. B. Dutta and N. N. Godbole. Watson and Sudborough established a relationship between the refractive index and the iodine value of a number of fatty oils. The unsaponifiable matter has been examined in some cases and phytosterols of known and unknown types have been characterized. A number of bitter principles have been isolated from various sources. Of these may be mentioned that from Bondercella (P. C. Ghose, T. Katti, S. S. G. Sirker), from Andrographis (S. S. G. Sirker), from Corchorus (N. Sen), etc. active principles of the following plants have been isolated and investigated: rottlerin from *Kamala*, a principle from *Aegle Marmelos*; from plumbago; from *Cuscuta reflexa* (S. B. Dutta); from *Ayapan*, *Piper chaba*, Ananas Sativa and Gardenia Lucida (P. K. Bose). A number of alkaloids have been isolated and characterized from *Rauwolfia serpentina* (Siddiqi); from *Holarrhena Anti-dysenterica* (S. Ghose); Vasicine has been isolated from *Adhatoda Vasica* (T. P. Ghose); alkaloids from certain species of *Ephedra* (S. Krishna); also from *Toddalia* and *Hedyotis* (B. B. De). *Erythrine Indica* and *Cryptocryne spiralis* have been examined by S. N. Chakravarti. This line is being actively pursued in various Indian laboratories and much useful information may be expected in a few years. Aesculine and scopoletine were isolated by Simonsen in 1916, who also elucidated the structure of morindone (1918).

Synthetic work on certain naturally occurring anthraquinone derivatives was carried out by P. C. Mitter and his pupils who synthesized rubiadine, aloeemodin, munjistine and a number of methyl-oxyanthraquinones related to rubiadine, morindone and emodine. Starting from 3-methylalizarin, a 4-hydroxy derivative was obtained. Oxidation of the methyl group and subsequent reduction with $Na_2S_2O_4$ led to an elegant synthesis of munjistine. Again starting from 2-hydroxy-3 methyl anthraquinone by

nitration and methylation, 1-2 dimethoxy derivative was obtained. Dimethylation and oxidation followed by reduction gave rubiadin. Another colouring matter, oroxylin A from *Oroxylum Indicum*, has been proved by R. C. Shah to be 6-methoxy-5 : 7-dioxyflavone. T. S. Wheeler studied the reactivity of chalkone derivatives and developed a method for synthesizing flavones like chrysene. The synthesis of a number of chromones and flavones were described by P. C. Mitter and his students. Venkataraman also described the synthesis of a large number of oxy-chromones, oxy-flavones and iso-flavones.

Heterocyclic compounds

Work under this heading comprises a large variety of N, O and S compounds prepared by a variety of condensation reactions carried out mainly by P. C. Guha and his co-workers, S. C. De, T. N. Ghose, T. K. Chakravarti and many others in Dacca and Bangalore. The following are some of the more outstanding types of compounds prepared and described: dithiourazole, various ring compounds from hydrazo mono- and di-thio-carbonamide, *o*-aminophenylsemicarbazide, diethylxanthoformate, *o*-aminophenylhydrazine, thiocarbohydrazide, ethylcarbethoxythiocarbamate, thiosemicarbazide, *o*-thiocarbamidobenzoic acid and substituted carbohydrazides. A study of the reversibility of Michael condensation was also undertaken by Guha and T. N. Ghose, using hydroxylamine on mustard oils and ethyl carbamate on unsaturated esters, etc. A number of azines, triazoles, etc. were also prepared. S. C. De has also studied the formation of a large number of thiozoles, thiodiazoles, triazoles, thiazines and thiodiazines.

H. K. Sen and his co-workers, U. Bose and C. R. Barat, synthesized a number of reduced pyridine, quinoline and isoquinoline derivatives by the union of oxymethylene ketones and β-diketones with compounds like cyanoacetamide, and sought to elucidate the mechanism of such reactions. The alkylation of oxymethylene ketones and the action of diazonium salts on them were used for this purpose. New types of acridones, phenanthridones and α-pyrones were synthesized by an extension of these reactions. P. K. Bose synthesized a number of thiodiazines, thiosemicarbazones, benz-thiazolequinazolines, etc. and also studied the benzidine rearrangement in the heterocyclic series. Among the many interesting syntheses of heterocyclic compounds by J. N. Ray and his co-workers, mention should be made of those of oxy-quinazolines by the action of acylamines on urethanes; of corydaline from the azide of 3 : 4 dimethoxy phenylpropionic acid; of phthalazines; of palmatine by a method analogous to that of Perkin, Ray and Robinson's synthesis of berberine; of homologues of laudanosine and of furano quinolines bearing the same skeletal arrangement as skimmiannine. Important work was described on the constitution and synthesis of vasicine. Possibly useful

compounds in the pharmacological sense were synthesized by Ray, and of these may be mentioned 2-oxynaphthylglyoxalino and pyrazoleno-quinolines; pyrrolindoles; quinolino-pyrones. *p*-amino-benzoylamino-methylhydrocotarnine was synthesized and found to be a good corneal anæsthetic.

R. C. Shah synthesized a number of 2-phenyl-4-oxy-3-carb-ethoxy quinolines; *N*-carbethoxy-phenyl-benzamidines and other types of amidine derivatives. Phenanthrolines and di-quinolines were described by T. S. Wheeler and his co-workers. Some important synthetic work in the alkaloid group was described by S. N. Chakravarti. Iso-opianic, ψ-opianic, *m*-opianic acids have been synthesized by elegant methods; a general method has been described for the synthesis of *O*-aldehydocarboxylic acids and of substituted phthalonic acids; methoxy and dimethoxy-homo-phthalic acids have also been synthesized. The preparation of a series of dimethoxy-proto-berberin derivatives has been carried out by painstaking methods.

Oxygen ring compounds

Coumarin and its derivatives have received considerable attention at the hands of several workers. B. B. Dey prepared a large number of benzene-substituted coumarins by the usual reactions. He and his co-workers studied the addition of sodium sulphite to coumarins and found that the addition is influenced by the presence of substituting groups. The addition products on boiling with 20% alkali gave the corresponding coumaric acids. Coumarin-3-acetic acid [synthesized by (1) condensing *O*-hydroxy aldehydes with sodium succinate and succinic anhydride, and (2) by the condensation of phenols with acetosuccinic ester] and also coumarin-4-acetic acid were shown to have a methylene group reactive towards aldehydes. The compounds with *p*-oxybenzaldehydes and vanillin showed interesting colour-reactions on alkalification. The constitution of β-naphthopyrone was established by synthesis. The geometric isomerism in this group was shown to depend on the nature of substituents and some stable cis-acids were prepared. The Pechmann conditions of synthesis were shown to yield generally coumarins only but in the case of β-naphthol the corresponding chromone was also obtained. Similar investigations were carried out by D. Chakravarti who studied the influence of substituents in the 2 components in a coumarin synthesis and also the effect of different condensing agents. He also used the reaction to establish the constitution of certain substituted phenols and coumarins. B. B. Dey has also synthesized a number of quinolino-α-pyrones which on treatment with alkali readily yielded the comparatively stable cis-acid thereby affording evidence in support of the hypothesis that groups like the nitro, amino, or quinolino stabilize the pyrone ring and yield stable cis-acids. Foro-coumarins were prepared by J. N. Ray. The work of Venkataraman and

his co-worker on chromones, flavones and iso-flavones have already been mentioned.

General

In this group may be mentioned the studies carried out by P. Neogi and his pupils on the action of nitrous acid on amines; the preparation of aliphatic nitro compounds from nitrites; of a number of metallic hyponitrites; of organic mercury compounds from phenols, phenol ethers and aromatic amines. They studied the phenomenon of geometric inversion of unsaturated acids brought about by exothermic reactions. The attempts of Neogi and co-workers at resolution of co-ordinated inorganic compounds into optical isomers have resulted in the resolution of triethylene-diamino-cadmium chloride, bromide, iodide and sulphate and triethylene-diaminozinc chloride and sulphate. A series of interesting organo-arsenic, antimony and mercury compounds were prepared by N. C. Niyogi with the object of obtaining therapeutically active compounds. He also established the constitution of 'ureastibamine'.

Much work has been carried out by B. K. Sing and his pupils on the dependence of optical rotatory power on the chemical constitution of a series of compounds obtained by condensing aromatic mono- and diamino-compounds with camphor quinone, and incidentally some products of exceptionally high molecular rotation have been described. They also used the determination of rotatory power for differentiating between isomeric, tautomeric, and polymeric bodies from polymorphic bodies and made an extensive study of the mutarotation of oxymethylene camphor. P. C. Guha has also studied camphor derivatives showing very high rotation and the problem of Walden inversion as applied to the conversion of *d*-tartaric acid into *l*-acid.

An interesting demonstration of the existence of the 4-methyl cylohexane ring in strainless configuration was provided by M. Q. Khudah who isolated 4-Methyl Cylohexane-1-carboxy : 1 acetic acid in four isomeric forms. He and his pupils also studied the keto-lactol tautomerism in the δ-keto-acids from the methyl-cyclohexanones.

The problem of orientation in the benzene series has been studied off and on by several workers and some work has been done on the influence of nuclear substituents on side chain reactions. The work in this field however is not easily summarizable. In this group the work of Simonsen has already been described. Sudborough studied the alcoholysis of a number of aliphatic and aromatic esters with a view to study the hindering influence of *O*-substituents on the process. P. S. Varma has carried out extensive halogenations of aromatic compounds and has successfully introduced iodine into a number of benzene derivateries.

An extensive study has been made by K. G. Naik and his pupils of the action of sulphur mono- and dichloride, thionyl chloride and chlorosulphonic acid on a number of types of

compounds containing the reactive methylene group, especially mono- and dibasic acid amides and cyanoacetamide. The introduction of mercury into such molecules has also been studied using mercury acetate and mercury acetamide.

Another systematic series of investigations were carried out by (the late) A. N. Meldrum and his co-workers who studied the condensation of chloral on various acetamides and used the reduction of the -CH(OH)CCl_3 group in these products for the synthesis of cochinillic, carminic and α-coccinic acids. They also prepared and determined the constitution of a number of nitro- and sulpho-salicylic acids. From the chloralides of oxybenzoic acids they synthesized substances like *m*-hemipinic acid and also some phenyl-acetic acids corresponding to gallic and other poly-oxyacids.

P. K. Bose has found that *O*-dinitrobenzene is a very suitable reagent for the detection of reducing sugars and polyhydroxy-benzenes.

V. Applied Chemistry.

In India, natural products constitute a vast source of raw materials and their proper utilization and scientific study being of great economic importance to the country, have received due recognition from various workers.

Oils and fats

The Departments of Industries in the various provinces have surveyed the quality and quantity of different oil seeds. Refining of various oils and the butter fat (*Ghee*) has been studied by Chatterjee, Chowdhury and Das, Menon and Menon and Datta, while their hydrogenation has been studied by Patel and by Mukerjee. Chemical examination of Malabar Sardine Oil and isolation of fatty acids from the same have received attention from Sudborough and co-workers, while the fatty acids of the common freshwater carp, *Labeo rohita*, have been isolated by Choudhury and Sarkar and the oil of the Indian Shad, *Hilsa ilisha* has been analyzed by Datta and Goswami.

Composition of oil from jute seed has been studied by Sen; oil of 'Cantharis' has been investigated by Iyer and Iyer; oils of '*Datura Stramonium*' Linn., '*Aristolochia Indica*' Linn., *Butea frondosa* and *Psarolea corylifolia* have been studied by Manjunath and co-workers. Krishnan and co-workers have investigated a corn and various other oils, while Watson, Simonsen, Sudborough and others have also studied the composition of various seed oils from indigenous sources. Dikhit and Datta have investigated Indian '*Bel*' (*Aegle Marmelos*) oil and have classed it as a drying oil having purgative action. Goswami's work on the composition of boiled oils and his synthesis of ring glycerides of dibasic acids with a view to elucidate the constitution of oils may also be mentioned here.

A possible new use of vegetable oils and unsaturated fatty acids for the manufacture of lubricating oils, synthetic resins

and moulding powders may be deduced from the work of Chowdhury, Chakraborty and Mazumdar on the polymerization of unsaturated fatty acids and their glycerides.

Goswami and Basu have put forward a new analytical constant, hypochlorous value for the determination of unsaturation and the method is reported to be independent of time factor, and allows simultaneous determination of the saponification value. Sudborough and co-workers have studied the relation between iodine values and refractive indices of oils. Detection of mineral oils in vegetable oils has received attention from Guthrie, while the refractometric method has been utilized for the quantitative estimation of adulterants in butter fat (*Ghee*) by Godbole and Sadgopal who have also suggested a modification of the methods for the determination of 'A' and 'B' values of oils.

Soaps

The suitability of a large number of vegetable oils for the manufacture of soaps has been investigated by Datta and co-workers, Duke and Sen and others. In the selection of suitable oils and fats for a proper blend, the I.N.S. and S.R. numbers of Webb were found inadequate. Das Gupta has, therefore, suggested two new factors, S/T and I/T, the former being the ratio between saponification value and the titre while the latter is the ratio between iodine value and titre. Datta has suggested a new number, called the hardness number, for the purpose, which is given by the following expression :—

$$\text{I.N.S.} + \text{Titre} \times 3{\cdot}7.$$

For toilet soaps, this number should lie between 299 and 309, while maximum detergency suitable for washing soaps was obtained with a hardness number of about 279.

The problems of preventing defects in soaps in tropical climates have received due attention from several investigators. The causes of the sweating of soaps have been investigated by Godbole and Sadgopal, Das Gupta, Goswami and Chatterjee. Chatterjee attributes the phenomenon to 'syneresis' caused by gradual transformation of soaps from gel to crystalline structure, but other investigators maintain that sweating is due to the presence of low molecular and unsaturated acids and to the presence of free glycerine and alkali in soaps.

The causes and prevention of cracking of toilet soaps have been dealt with by Sadgopal. Deterioration of soaps by oxidation, and its prevention has been dealt with by Levitt. Proper selection of raw materials, addition of small quantities of thiosulphate and rosin, presence of traces of free alkali and careful drying help in preventing oxidation of soaps. Mitter has devised special drying chambers for soaps, and the use of sodium carbonate to replace a part of caustic soda in the saponification of oils and fats has been suggested by Datta and Das. Goswami suggests the utilization of glycerine in soap lye by oxidation into formaldehyde.

Chatterjee has found that *Mohua* oil is completely saponified by 40% alkali in the cold and has, therefore, suggested its extensive use in cold process soaps.

Essential oils

Though India has an extensive supply of raw materials for the manufacture of perfumery, this industry is hardly developed in India. A survey of raw materials has been given by Sadgopal. Work of a fundamental nature on the constitution of several essential oils has been done by Simonsen, Sudborough, Sanjiva Rao, Moudgill and others, and the Mysore Government Factory for the manufacture of Sandal wood oil owes its origin largely to the incentive given by the Indian Institute of Science, Bangalore. Watson and Mulany have investigated the preparation of camphor from pinene and have also determined the pinene content of Indian terpentine oils.

Wood and other cellulosic substances

The Forest Research Institute at Dehra Dun has done valuable work on Indian timbers. Fitzgerald and Kapur have studied the air- and kiln-seasoning of Indian timbers. Raitt's work, demonstrating the suitability of bamboo for paper pulp, has opened up a cheap and inexhaustible source of raw material for the paper pulp industry. The preservation of timbers by treatment with antiseptics has received attention from Pearson, Warr, Popham and others. Kamesam has been able to discover a highly active preservative containing chromium and arsenic. The importance of rotproof and termite proof timbers, not only for railways and the mining industry, but also for structural purposes, both outdoor and indoor, cannot be exaggerated. It has been claimed that even the soft wood, if properly treated, will last for at least 20 years and can, therefore, compete with steel for structural purposes. Nagle has tested Indian timbers for veneer and plywood. Various Government Departments have made a survey of various woods suitable for the match-making industry; Datta has bleached *Gangwa* wood to make it suitable for matches. Distillation of certain woods and examination of the tar obtained has been done by Sudborough, Watson and co-workers.

Saccharification of wood and other lignocelluloses with a view to the production of power alcohol has been studied by several investigators. Thus power alcohol in good yield has been obtained from *Gangwa* wood and from water hyacinth by Sen and co-workers, from rice straw by Deshpande and from bagasse by Fowler and Banerjee.

In an important communication, Sen and Das Gupta claim to have obtained large quantities of liquid products directly from cellulosic substances without saccharification by the action of two new spore forming organisms isolated by them from horse dung. Symbiotically, these organisms decompose over 90% of the cellulose, producing 82% of its weight of volatile acids (acetic acid) and

10–15% alcohol without the production of any methane or hydrogen —the only gases evolved being CO_2 and H_2S.

Jute

Of the cellulosic fibres, jute has received considerable attention from Chowdhury and co-workers. They have found that lignin in jute can be progressively removed either by treatment with a creosote-pyridine mixture or by the action of chlorine peroxide on the moist fibre when some of the fibre qualities, particularly the colour, improve. Lignin, however, serves to protect the binding material in jute and its complete removal considerably weakens the fibre. Sarkar has improved the tensile strength of jute and its resistance against rot by treatment with formaldehyde while these properties together with the elasticity have further been improved by Chowdhury and his students by treatment with suitable antiseptics. Bagchi has explored new applications for jute and showed that jute nitrocellulose can be made as stable as cotton nitrocellulose and that owing to its low viscosity and higher solubility, it is more useful for the lacquer industry. Chowdhury attributes the fibre qualities of jute to its fundamental structure and composition, and finds that the cellulose molecule of jute is actually smaller in length than the molecules of cotton cellulose. The differences in the physical and chemical properties of the two celluloses can thus be explained. Besides cellulose, the nature of the accompanying matters has profound influence on the properties of the fibre and has, therefore, been investigated. The cementing matters have been found to consist of polymerized hexoses and pentoses, particularly xylose, combined with uronic acids whose presence explains the behaviour of the fibre towards basic dyes. Sarkar has studied the constitution of Jute lignin. Barker in his review of jute industry in India draws attention to the importance of these fundamental investigations for manufacturing practice.

Sugar

The sugar industry does not appear to have received the attention that is due to it. In 1925, Hutchinson and Ramayyar studied the problem of loss of sugar by inversion and since then no other work on this important problem seems to have been published. Srivastava has discussed the Open-Pan-System of white sugar manufacture, while sugar from palms in Hyderabad has been investigated by Bhate.

With the growth of the Indian Sugar Industry, the utilization of molasses presents an important problem. Watson has tried to recover sucrose from cane sugar molasses, while its utilization for alcohol, acetic acid, acetone or as cattle feed has been suggested by others. Sen and Das Gupta have obtained 67% acetic acid and 19·5% alcohol from molasses by the action of the organisms isolated by them from horse dung. Dhar recommends its use as a fertilizer, and claims that besides introducing organic matter, it serves to conserve the valuable nitrogen of the soil.

Tanning

In the field of tanning, the Departments of Industries in various provinces have made a survey of the possibilities of this industry in their respective provinces while a large number of workers have examined the suitability of indigenous tanning materials and their tannin content. Tannery Waters have received attention from B. M. Das in Calcutta and Guthrie in Madras. The various kinds of stains in hides and skins, their causes and prevention, have been studied by Guthrie, Patwardhan and others.

Lac and Shellac

Under the auspices of the Lac Research Institute at Ranchi and under the guidance of G. Fowler at Bangalore, a large number of workers have devoted attention not only to cultivation but also to bleaching, chemical composition and physical and mechanical properties of Lac and Shellac. The most important industrial development in this field is the recent utilization of shellac for moulding powders by Gardner and co-workers.

Coal

The importance of coal as a fuel has attracted several investigators. The chemical composition of Indian coals has been investigated by Bhattacharjee and by Mahadevan while the action of solvents on coal has been studied by Datta Roy. The proximate composition of coals has been determined by Fermor who has also studied the relationship between specific gravity and ash content of certain coals. Cleaning of Indian coals has been dealt with by Bose and Gupta, while Randall applied the Froth Flotation process for the same purpose.

Low Temperature Carbonization of Indian coals has been studied by Standley, Fermor, and Sen and co-workers. Sen, Ray and Guha have improved the method of low temperature distillation by admixing the coal with its own weight of tar, the result being a much higher yield (50%) of primary tar. Sen and Ghose have improved the proportion of neutrals in the tar by adding iron filings, potassium acetate and sodium carbonate in the ordinary low temperature distillation, thus obtaining a better quality of tar with low neutral phenol ratio, which is suitable for internal combustion engines.

Gaseous Fuel

Generation of gaseous fuels from water hyacinth has been investigated by Sen and Chatterjee, while the production of combustible gases from sewage sludge and vegetable matter has been studied by Griffin. J. C. Ghosh and Chakravarty have investigated the catalytic formation of methane from carbon monoxide and have been able to evolve satisfactory catalysts for the production of fuel gases rich in methane. In course of this work Ghosh, Chakravarty and Bakshi have prepared a very active catalyst which enables the simultaneous determination of the equilibrium at temperatures between 400° and 500° of the following technical gas reactions :—

$$(1)\ CO+H_2O \rightleftarrows CO_2+H_2; \quad (2)\ 2CO+2H_2 \rightleftarrows CH_4+CO_2;$$
$$(3)\ CO+3H_2 \rightleftarrows CH_4+H_2O.$$

Ghosh and Sen have also been able to synthesize higher paraffins from water gas at ordinary pressure by the use of suitable catalysts.

Absorbents

Chowdhury and co-workers have prepared highly active mixed absorbents consisting of alumina and silica gels and have used it for various industrial purposes such as recovery of benzol from coke oven gases, decolorization of vegetable oils and desulphurization of mineral oils. Rai Choudhury has also prepared activated charcoal of high activity suitable for industrial application.

Chemicals

In the field of chemicals, Marsden has drawn attention to tamarind as a raw material for the manufacture of tartaric acid and the lime for citric acid. Sudborough and co-workers have extracted caffeine from tea waste, while Watson and Sen have prepared strychnine and brucine from *Nux Vomica*, and Watson and Mulany have obtained camphor from pinene obtainable from terpentine oil. Chowdhury and co-workers have obtained benzoic acid and phthalic acid in satisfactory yields by the catalytic oxidation of toluene and naphthalene respectively in the vapour phase. Watson and Jatkar have also used solid catalysts for the production of ether. J. C. Ghosh and Bakshi showed that if ceria were added to a copper catalyst as promoter to the extent of 1%, continuous dehydrogentation of methanol to formaldéhyde can be effected even at 200°.

Electrochemical Industries

H. K. Sen has been able to devise an electrolyzer for conducting electrolysis of a 25% soda solution in a closed system on a semi-technical scale producing hydrogen and oxygen under a pressure of 120–150 atmosphere, thus producing hydrogen under high pressure suitable for pressure hydrogenation. The problems of dry cells have been investigated by Ray and Ray and Vepa has measured the potential of dry cells with magnesium chloride electrolyte. The art of chromium plating has been discussed by Parekh, and theoretical investigation of this process has been conducted by Syed Hussain. Mention may also be made here of the production of photographic plates by Ker.

In the field of inorganic industries, mention may be made of the manufacture of ultramarine blue from Indian raw materials by Mukerjee ; Mukherjee and Drane have examined the suitability of Indian sands for glass industry, while Dixon has devised a furnace suitable for glass making under Indian conditions. Datta has used waste glass as a source of sodium silicate. It may be expected that the recent foundation of a research laboratory by the Tata Iron and Steel Co. will serve to foster research on the alloys of iron and steel in India.

VI. Biochemistry.

The credit for initiating researches in Biochemistry in India goes to Prof. Fowler of the Indian Institute of Science at Bangalore. Besides certain miscellaneous investigations, interest has centred round the following principal lines of biochemical research : nutrition and deficiency diseases, enzyme action, and soil microbiology.

Nutrition and Composition of Food-stuffs

The pioneer work of McCarrison indicated that the Punjabi diet was the best and the Madrasi diet the worst in India. Considerable work of value has been done on problems of nutrition in general and on the factors responsible for such diseases as beri-beri and goitre, a fuller account of which is given in another chapter of this review.

Pulses

Investigations at Bangalore on proteins of pulses were concerned with the extraction with different solvents, purification, and estimation, of the individual amino acids. Elensinin, the alcohol soluble protein of *Ragi* (*Elensine Coracana*) was extracted and analyzed by Narayana and Norris in 1928. Sundaram, Norris and Subramanyan found the chief proteins of *Cajanus indicus* to be two globulins, one of which was deficient in tryptophan. Narayana extracted and analyzed the globulin of Bengal and horse gram and found them deficient in cystine and tryptophan. The globulin fraction of *fenugruck* has been found by Sreenivasa Ram and M. Sreenivasaya to be characterized by a surprisingly high content of histidin while the protamin fraction was found to contain higher percentage of cystine and tryptophan. Miss Kamala Bhagvat has studied the globulins of the cowpea (*Vigna catiang*) and of the aconite bean (*P. Aconitifolius* Jacq.) from the analytical and physico-chemical point of view. She has also done some work on the non-protein nitrogen of different pulses.

At Dacca, Basu and co-workers (Nath, Ghani, Mukherjee and Basak) have studied the biological value of the proteins both by the balance sheet and by the growth methods, and have investigated the supplementary relations between the proteins of different food-stuffs. Extraction and chemical analysis of the proteins have also been carried out to discover in which essential amino-acids a food-stuff is deficient. Green gram proteins appear to be superior to lentil proteins both with regard to maintenance of nitrogen equilibrium and growth-promotion and lentil appears to be deficient in cystine. *Aus* and *Aman* rice are equally efficient for nitrogen balance but *Aman* is much superior as regards growth-promotion ; here again cystine or methionine appears to be the deciding factor. There is a supplementary relation, so far as growth is concerned, between rice and pulse proteins. Soya bean proteins appear to be of good quality. Field pea and *Lathyrus sativa* proteins are equally efficient for maintenance of nitrogen

balance but *Lathyrus sativa* fails to cause any growth due to loss of appetite caused by a toxic factor. Lathyrism could not be induced in rats. *Hilsa* (*Hilsa ilisha*) fish proteins appear to be inferior to the proteins of *Rohu* (*Labeo rohita*). Damodaran at Madras, has made an exhaustive study of the hydrolytic products of proteins, and is now investigating the proteins of the cashew nut. Prof. Niyogi and co-workers at Bombay have also done some work on the nutritive value of the Indian pulses. Mention should also be made of the interesting work of Sankaran and Ranganathan on the molecular formula of thyreo-globulin.

Rice

Early work at Coonoor showed that the quality of rice depended a good deal on the environmental conditions at the period of growth. Basu and Sarkar have carried out extensive analysis of a large number of *Aus* and *Aman* varieties of rice in their different states, whole rice, dehusked rice, polished, parboiled and non-polished rice. *In vitro* digestibility studies of starch of different varieties (Basu and Sarkar ; Basu and S. P. Mukherjee) of rice and also of proteins by different enzymes have revealed the superiority of *Aman* over *Aus* rice. At Bangalore, the changes in rice taking place through storage, influence of season and manuring on quality of rice, and thorough parboiling have been studied. Attention has also been drawn to the heavy loss of phosphorous through milling and suggestions made for the use of unpolished and coloured rice. The chemical composition of 200 common Indian food-stuffs has been determined by Ranganathan, Sundararajan and Swaminathan. N. C. Dutta has examined the metallic contamination of Indian food-stuffs and has shown how the peculiar nature of the food materials concerned in many parts of India is responsible for the heavy corrosion of the cheap metallic containers that are commonly used.

Vitamins

Aykroyd and co-workers have determined the carotene and Vitamin A requirements of children and measured the growth of embryonic nervous tissue in plasma of Vitamin A deficient fowls and rats. Radhakrishna Rao has made a study of Xerophthalmia and Trigeminal nerve degeneration in Vitamin A deficiency. Wilson and Ahmed have studied the metabolism of carotene and the absorption of carotene and Vitamin A in the human subject. De has carried out similar experiments in rats and has developed a spectrographic method for the estimation of Vitamin A. B. N. Banerjee has studied the problem of the preservation of Vitamin A in *Ghee* and has shown that a number of factors, such as, moisture, heat, adulteration with hydrogenated oils, contribute to the destruction of this constituent. Investigations of Indian fish liver oils have shown that many of them are richer than cod-liver oil in Vitamin A, though less potent that halibut liver oil (B. C. Guha).

Guha and co-workers (Biswas and Chakraborty) have isolated Reno-flavin from ox-kidney, have drawn attention to the (*a*)

multiple nature of Vitamin B_2 of which lacto-flavin is one component, and (*b*) the relation between dermatitis, pellagra and eye-diseases and deficiency in Vitamin B_2. They have also measured the Vitamin B content of rice, water of the green cocoanut and of poppy seeds. Aykroyd and Krishnan attribute stomatitis in school children to Vitamin B_2 deficiency which can be cured by dried yeast or skimmed milk. The solubility and isoelectric point of Vitamin B, have been determined by Sankaran and De.

The problem of the biosynthesis of Vitamin C has received attention. Of all the common sugars, mannose was found to produce ascorbic acid in experiments with rat-tissues carried out both in Vitro and in Vivo. The enzyme system concerned has been extracted from germinated phaseolus mungo. Experiments in this connection have also been carried out with the tissues of the monkey, rabbit, pigeon, etc. in order to throw light on the mechanism of this biochemical transformation. Some common Indian fruits like the mango and lichi have been found to be much richer in Vitamin C than lemon and orange (Ghosh and Guha). Ahmed and Chakraborty have determined the Vitamin C content of a large number of Indian food-stuffs, and the excretion of Vitamin C in Urine. Srinivasan has obtained a powerful oxidase specific to ascorbic acid in drumsticks, and Chakraborty has examined various plants and animal tissues for the existence of this oxidase. Investigation on the state in which ascorbic acid is present in plant tissues indicates that part of it is ascorbigen which can be extracted from dried cabbage with chloroform and ether and which releases ascorbic acid on heating in an atmosphere of nitrogen (Guha).

The dissociation constants of pure ascorbic acid have been measured and found to be $6{\cdot}3\times10^{-5}$ and $2{\cdot}7\times10^{-12}$ (J. C. Ghosh and Rakshit). It has been found, contrary to the observation of previous investigators, that ascorbic acid carefully freed from copper salts does not readily undergo auto-oxidation, and that the catalytic action of copper salts is destroyed by iodine ions which precipitate cuprous iodide. Sulphuretted hydrogen, organic sulphur compounds, and suspensions of chlorophyll have been found to be powerful inhibitors of this auto-oxidation (Ghosh and Rakshit).

Enzyme Action

One of the first major problems investigated by Dr. Fowler and his associates (Messrs. Mumford, Y. D. Wad and A. G. Gokhale) was the manufacture of acetone, which was greatly needed as a solvent during the War. The fermentation process, originally evolved by Dr. Weizmann, was successfuly applied and large quantities of acetone produced from *jowar*.

Fowler and collaborators also studied the enzymes of *lantana* leaves, the biochemistry of *Mohua* flower with a view to obtaining a greater percentage of alcohol by fermentation, the use of antiseptics in the manufacture of glue and gelatine, the nature of bacteria

associated with rice and other cereals, the biochemistry of the indigenous indigo vat, the production of power alcohol from waste cellulose materials, the bacterial oxidation of alcohol to acetic acid and the retting of cocoanut husk (Behram, Bhate, Joshi, Habib Hassan, Wad, Gokhale, Sreenivasan, D. L. Sen, Banerjee, Subrahmanyan, Marsden and others).

Among the recent contributions from Bangalore, special mention must be made of the series of researches on the 'in vitro' digestibility of proteins, and on the nature of non-protein nitrogen of pulses. Enzyme digestion was successfully applied and the various attendant changes followed by elegant and rapid physical and physico-chemical methods. New and improved types of dilatometers were devised and applied to the study of various biochemical problems. Studies on the nature of amylases adduced further evidence to support their non-protein character. Fresh light was thrown on the mode of enzyme inactivation by heat and activation by neutral salts. Enquiries on phosphatases of animal and vegetable origin were started and their activation under different conditions studied. Different lipases were also compared in regard to their action on various oils and fats and a new technique was developed for the detection of adulteration of ghee and butter. Conductometric changes consequent on enzyme reaction were followed and elegant methods for the estimation of micro-quantities of biological products like urea and arginine developed (Sreenivasya, Giri, Iyenger, Shastri, Miss Bhagvat, Menon, Rao, Acharya, Srikhande and others). Mention must also be made of the studies of Dalvi on the fermentation of tanliquors, of Deshpande on the fermentation of straw and of Reddy and Subrahmanyan on *Sonti* fermentation. It is interesting to note that Guha and Das have discovered a new enzyme inositol dehydrogenase in the brain and kidney tissue of the rat. H. K. Sen has studied the activity of carboxylase in different varieties of yeast on a Keto caproic acid and dimethyl pyruvic acid (Sen). Symmetrical and unsymmetrical dichloroacetones were reduced by strongly fermenting sugar solutions with excess of yeast (Sen, Sen and Barat), producing in good yields the corresponding dichlorisopropyl alcohols, of which the unsymmetrical one was optically active. The strongly reducing property of fermenting yeast was taken advantage of in developing a theory of alcoholic fermentation based upon the reduction of ether or anhydride linkages in the sugar molecule (Sen and Barat). Sen and Banerjee examined the decomposition of pyruvic acid by various substances, organic and inorganic, and have shown that some complex protein materials like gelatin, egg albumin, etc. act as catalysts. The action of ultraviolet light on these so-called 'Synthetic' enzymes was further studied (Sen and Banerjee), and inhibition was noticed in several instances

as with natural enzymes. Gelatin and tyrosine did not accelerate the diastatic activity, but would protect it in the presence of ultraviolet light at *p*H 9·6. A papain-like enzyme has been obtained from the milky juice of *Calotropis gigantea* and its purification and activation by glutathione and ascorbic acid studied (Basu and Nath). The action of a number of basic and acidic dyestuffs and of some narcotics on trypsin and on papain has been investigated by Basu and R. K. Chakraborty with the object of elucidating the nature of the enzymes. Basu and S. P. Mukherjee have established the identity of the Schardinger enzyme and xanthine oxidase of milk. Glutathione as well as ascorbic acid (Basu and S. P. Mukherjee) has been found to accelerate the aerobic oxidation of xanthine and aldehydes by milk enzyme. Basu, Nath and S. C. Chakravorty found that the oxidising enzymes in betel leaves were capable of oxidising many substances.

B. B. Dey has devised a new method for estimating the peroxidase activity of Indian plant saps using hydroquinone as the substrate. The quinhydrone formed is estimated after filtering it by Valeur's method.

The influence of various factors on the peroxidase activity has been studied with respect to the sap from Chow-Chow which was found to be much richer in the enzyme and free from catalase.

Oxidation of biological systems

In course of their studies on the induced oxidation of carbohydrates, fats, etc. at ordinary temperatures, Dhar, Palit and Mittra have shown that substances like glucose, starch, cane sugar and fatty acids, when mixed with substances like sodium sulphite, freshly precipitated ferrous, cerous, manganous and other hydroxides, are oxidised to CO_2 and water. They have shown by oxidising tartaric acid, starch and sugar that the oxidising power of hydrogen peroxide is greatly accelerated by ferric and ferrous salts, and that citrates and tartarates are directly oxidised to carbon dioxide by air in the presence of sunlight and inductors like ferrous hydroxide. They also conclude that the phenomenon of oxidation in the tissues is probably due to the induced action of easily oxidisable substances like glutathione, insulin, ascorbic acid, and suitable compounds of iron, copper and manganese.

J. C. Ghosh and Rakshit have made a quantitative study of the oxidation of sugars by air in presence of ceric hydroxide sol and cerous hydroxide gel and detected the presence of ceric hydroperoxide as an intermediate product. Inhibition was noticed with glycerine and results have been explained on the basis of Wielands' Dehydrogenation Theory. Physiologically active sulphur compounds like cystine were found to be easily oxidised by hydrogen peroxide in presence of tungstic acid and molybdic acid to cysteic acid and even to the stage of formation of sulphuric acid (Ghosh and Kar).

Oxidation-Reduction potential in Biological systems

J. C. Ghosh and co-workers (Ganguly, Ray Choudhury, Ramachar) have investigated the conditions under which reliable results for the oxidation-reduction potential of biological systems like glutathione, cysteine, ascorbic acid can be obtained. They were able to eliminate the last traces of oxygen absorbed on the surface of electrodes or dissolved in solutions, bathing the electrodes by cathodic reduction with hydrogen, and removal of the hydrogen by a current of purest nitrogen and established the following equations for oxidation-reduction potentials :—

$$E = 0{\cdot}37 - \frac{RT}{F} \cdot P_H + \frac{RT}{2F} \cdot \log \frac{[\text{Dehydroascorbic acid}]}{[\text{Ascorbic acid}]}$$

$$E = 0{\cdot}079 - \frac{RT}{F} \cdot P_H + \frac{RT}{F} \cdot \log \frac{\sqrt{[\text{Cystine}]}}{[\text{Cysteine}]}$$

$$E = 0{\cdot}068 - \frac{RT}{F} \cdot P_H + \frac{RT}{F} \cdot \log \frac{\sqrt{[\text{Oxidised Glutathione}]}}{[\text{Glutathione}]}$$

Microbial Action in Soil

Considerable attention was devoted by Fowler and his associates to the transformations of organic matter and minerals of micro-organisms. The investigations on nitrogen transformations in activated sludge demonstrated the conservation and even fixation of nitrogen under conditions of vigorous aeration. These studies have led to the well-known Fowler method of composting waste minerals (Rege and Kotwal). Recent investigations by Subrahmanyan and co-workers have revealed the advantages of short period hot fermentation followed by anærobic degradation in closed chambers. Reference should also be made to their studies on soil Actinomyces, on the decomposition of different organic substances in swamp soils, and its bearing on the economy of carbon and nitrogen in the system, and to the observation that nitrate in soil is soon converted by micro-organisms into ammonia as soon as it is water-logged. De and Sarkar have found that added nitrates are rapidly assimilated by micro-organisms in water-logged soils when the ratio of energy carbon to nitrate nitrogen is greater than 30 ; when the ratio is narrower, a portion of the nitrate may denitrify slowly. De has also observed that fixation of nitrogen takes place in Indian paddy soils when water-logged and exposed to sunlight due probably to an algal process.

Dhar, Mukerjee and Kar have shown that by application of molasses, formation of ammonia is enormously increased provided there is sufficient aeration.

Snake Venom

Investigations have been carried out by B. N. Ghosh and co-workers on the mechanism of antigen antibody reactions and on the constituents

of the venoms of Indian snakes. The neutralization of antigens by antibodies has been accounted for by an equation deduced on the assumption that one of the reactants is absorbed on the surface of the other and that the absorption is preferential. The equations have been successfully applied to explain quantitatively the neutralization of strepto-lysin, cobra-hæmolysin, diphtheria toxin and ricin by their corresponding anti-substances (Ghosh). Ghosh and Ray have studied the effect of electrolytes on the rate of flocculation of toxin—antitoxin mixture of diphtheria and tetanus. Venoms of *Naja naja*, *Vipera russelli* and *Echis carinata* contain a proteolytic enzyme very similar (Ghosh) to trypsin and an oxidase, oxidising hæmoglobin to methæmoglobin. The neurotoxin and hæmolysin of Naja Naja venom are strongly basic in their chemical nature and have no iso-electric point between pH 2·2 and pH 10·0 (Ghosh and De); with the aid of cataphoretic experiments using intercepting membranes the quantity of associated proteins has been greatly reduced.

Linton and his co-workers, Shrivastava and B. N. Mittra have been carrying out extensive investigations on the antigenic structure of *Vibrio choleræ* since 1932 under the auspices of the Indian Research Fund Association at the All-India Hygiene Institute, Calcutta.

Although his interests are mainly pharmacological, Chopra at the School of Tropical Medicine, Calcutta, with his co-workers has been carrying on researches on Biochemistry as well. Physical properties of blood sera (with S. G. Choudhury) electric charge of erythrocytes (with S. G. Choudhury) proteolytic enzyme in cucumber (with A. C. Ray) protein fractions of blood sera (with Mukerjee, Sundar Rao, G. S. Chopra, B. Sen and J. C. Gupta) of persons both normal as well as suffering from different diseases, colorimetric determination of lecithin, atebrin, etc. in blood; and indophenol reducing properties of urine (with A. C. Roy)—these are some of the subjects that have engaged his attention. Extensive investigations have been carried out by Chopra on the Indian Indigenous Drugs under the auspices of the Indian Research Fund Association. Systematic chemical examination of the indigenous medical plants has been done by Prof. Sudhamoy Ghosh of the Tropical School, and the constituents have been purified. Basu and Nath have isolated a stable sterol from the milky juice of *Calotropis gigantea* and Basu and R. K. Chakravarty another sterol from *Carica papaya*. Nath has isolated a crystalline sterol-like ketone from the Indian summer fruit *Artocarpus integrifolia*.

Spike disease of Sandal

An important enquiry was undertaken by Dr. Norris and co-workers several years ago on the spike-disease of *Sandal*. As the disease was causing serious ravages in Madras and Coorg, the enquiry was subsidized by the Governments of those provinces, and a special staff engaged for the study of the various aspects

of the problem. The series of biochemical memoirs published by M. Sreenivasaya and his associates and by A. V. Varadraja Ayengar have thrown fresh light on the nutrition of *Sandal* and the biochemical transformations associated with the disease. They have also led to measures of controlling its spread in nature. Sreenivasaya established the infectious nature of the disease and adduced evidence to show how it is spread in nature. In association with Rangaswami, he also demonstrated that the disease can be transmitted by insects. Among the several memoirs dealing with that aspect of the problem, special attention may be directed to a series of papers published by C. F. C. Beeson and N. C. Chatterjee on the fauna of *Sandal* forests and that of C. Dover on insect transmission of the spike.

PROGRESS OF GEOLOGY AND GEOGRAPHY IN INDIA DURING THE PAST TWENTY-FIVE YEARS.

By

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Contents.

I. Introduction.

Seventeen years ago the present writer had occasion to review the position of Geology in India when he stated 'in a country like India where the ground to be covered is so vast and the workers

so few, the disproportion between the work accomplished and that which yet awaits accomplishment is much greater and will remain so for a long time to come. The reason for this is obvious. The science of geology has held in the past and still holds, in respect to the sister sciences, an unenviable position in India. For, besides the inexplicable indifference of the educated people of India towards geology—a people who evolved in the past some of the earliest true concepts regarding the fundamentals of the Science of the earth,—it has not been fortunate in receiving that share of amateur contribution from men of liberal learning and culture who generally fill the public service of India and who have enriched the records of Indian natural history, ethnography, botany and archæology '.[1]

The position now happily is considerably altered, and though the great bulk of geological research yet continues to emanate from the official bodies, the Geological Survey of India and the Geological Departments of one or two States, there have been some very notable additions to it within the last fifteen years from some of the Universities, research students and the geological experts in the employ of some industrial firms, notably the Burmah and Attock Oil Companies. During the period under review the Asiatic Society of Bengal has published a number of geological papers ; the Mining and Geological Institute of India has greatly increased its membership and activities, the Geological, Mining and Metallurgical Society of India has been established, and the recently founded National Institute and Academies have published a few papers on Indian Geology.

The main lines of advance in our knowledge of Indian Geology and Geography may be classified under the following heads :—

The Archæan fundamental complex.

The Gondwana system of Continental deposits.

The Deccan Trap.

The Salt Range.

The Classification of the Tertiaries.

The Tectonics of the Himalayas.

The Indo-Gangetic Trough.

Recent Advances in Palæontology.

Economic Geology.

Geography and Geodesy.

[1] Presidential Address, Section of Geology, VIII Indian Science Congress, Calcutta, 1921.

II. The Archæan.

Archæan rocks cover nearly ¾ million square miles of India, constituting the main body of the Peninsular shield—a rigid crust-block that has played a passive rôle in geological history. As in other parts of the world these rocks present many difficult problems of stratigraphic sequence and correlation, still unsolved, but the concentrated work of the Geological Survey of India during the last 25 years in a few selected areas, viz., of Fermor and his co-workers in the Central Provinces, of Heron in Rajputana, of the Mysore geologists in South India and the vigorous efforts of the present Survey parties working in the Central Provinces and Chhota Nagpur, indicate lines along which these problems may ultimately be solved.

No system of classification of the Archæans of India hitherto proposed has met with any general acceptance and any attempt at correlating the outcrops of these rocks in distant areas must be regarded as entirely tentative and hazardous. The following table shows the chief divisions of the Archæans of the Peninsula arranged without any strict chronological order :—

Purana Group.	Vindhyan system ; Kurnool series ; Pakhal series ; Bhima series. Malani series ; Penganga series. Delhi system ; Cuddapah system.
	———Eparchæan unconformity.
Archæan Group.	4. Dharwarian. Aravalli system of Rajputana ; Sausar series of the C.P. ; Gwalior series ; Iron-ore series of Bihar ; Raialo series ; Gangpur series ; Bijawar series.
	———Eruptive unconformity.
	3. Granites of Madras, N. Arcot, Bihar ('dome gneiss'). Charnockites of Madras Presidency ; Champion gneiss of Mysore ; Norites of Coorg, Mica-pegmatites, etc.
	2. Schistose gneisses and schists including the schistose sediments of Mysore territories.
	1. Foliated gneisses of the Peninsula ; Bundelkhand gneiss.

(a) *Rajputana.*

Dr. A. M. Heron's work in Rajputana since 1908 has greatly clarified the problem of sedimentary Archæans in the N.-W. sector of the Peninsula (22, 24). Four distinct systems of crystalline rocks and variably metamorphosed sediments are proved in this area, separated from each other by well-marked unconformities,

each denoting a period of diastrophism and erosion. The grade of metamorphism present in these old rock groups is highly variable, some of these being still at places hardly distinguishable from shales, while the same rocks when traced along the strike to areas of tectonic plication and compression become schists or banded gneisses. At the base of this long sequence of sedimentary strata occur the oldest gneisses of India—the Bundelkhand gneiss, which is a granite, and the banded gneissic complex of the Peninsula—a paragneissic alteration product of primordial argillaceous and arenaceous sediments. This unique sedimentary pile ends at the top in an unconformable contact with the Vindhyans, a thick series of sediments which in the topmost part may represent a basal Cambrian horizon. The tectonics of Rajputana are of great interest as revealing the structure of the part of the Indian foreland whose northern promontory, the 'Punjab wedge' has played such a part in moulding the orientation of the Himalayan, and according to Mushketov, also of the Pamir and Ferghana, ranges (31). The main period of crustal deformation and igneous activity in Rajputana was the Purana Era. The orogenic activity was localized and more or less confined to the Aravalli belt from north of Delhi to Gujarat, so that outside of this orogenic zone the rocks, even though so ancient, are unmetamorphosed.

The Aravalli range

The Aravalli range, marking the site of one of the oldest geosynclines of the world, is still the most distinct mountain range of the Indian Peninsula, with summits of 4,000 to 5,000 feet. It was peneplaned in pre-Cretaceous times but has now been dissected in the central part, large tracts of western Rajputana remaining a peneplain. Structurally it is a closely plicated synclinorium of rocks of the Aravalli and Delhi systems, the latter forming the core of the fold for some 500 miles from Delhi to Idar in a N.E.-S.W. direction. Though the north-west flank of the synclinorium is a straight line, there is no evidence of a fault there. The curving east boundary of the fold, on the other hand, marks the line of the Great Boundary Fault of Rajputana, which brings the Vindhyans against Aravallis and Bundelkhand gneiss.

The Delhi system

The Delhi system, which may be taken as marking the commencement of the Purana Era, is characterized by a great variety and abundance of igneous intrusions and by an intenser grade of metamorphism than that observed in the older Aravallis (Archæans). This circumstance is explained by the fact that the Delhis were buried more deeply in the roots of the synclinorium than the underlying Aravalli rocks, which form the flanks of the fold and have thus escaped severe metamorphism.

The Purana Era in Rajputana was one of igneous and orogenic activity, localized and more or less confined to the Aravalli mountains.

(b) *Central Provinces.*

The Geological Survey has devoted a great deal of concentrated attention to the detailed large-scale mapping of selected Archæan areas with the result that some important data are now available for the correlation, on lithological grounds mainly, of the Archæans of adjoining terrains. The Archæans of Nagpur, Bhandara and Chhindwara districts (Sausar series) have been studied for twenty years by Sir L. L. Fermor. These Archæans (Sausar series) are a mixture of metamorphic sediments with igneous intrusives; they are classified into a number of stages of remarkable persistency, characterized by para-schists, amphibolites, granulites, marbles, large ore-bodies, metamorphosed lava-flows, and wide areas of streaky gneisses.

The Sausar series

The Sausar series, consisting of highly metamorphosed calcitic and pelitic sediments with a zone of richly manganiferous strata (Gondite series), is considered now to be stratigraphically older than the gneissic rocks of the Central Provinces. It is likewise taken to be older than the greater part of the Dharwars of Mysore; no older formation corresponding to the gneissic foundation of the Aravalli system is recognized in this region, as well as in the Central Provinces.

No upward passage of the Central Provinces Archæans into the pre-Cambrian and Cambrian sediments has been established, as the gneisses of Nagpur and Chhindwara are believed to be younger than the Sausars. These latter exhibit the following sequence: (1) Fine-grained biotite-gneiss. (2) Porphyritic (augen) and streaky gneiss. (3) Acid muscovite-gneiss and granite. The streaky gneiss of the Central Provinces occupying wide areas is believed by W. D. West to be of composite origin, the base being often provided by a granulitic rock into which the acid aplitic granite material is injected in bands and thin veins. West has brought forward evidence to show the complexity of folding present in these rocks, a *nappe* structure being apparently present near Nagpur, whereby different facies of the Sausar series, originally deposited far apart, have been brought into juxtaposition.

A less metamorphosed group of Archæan sediments, perhaps representing an upward extension of the Sausars, is separated under the name of the Sakoli series in the Bilaspur and Balaghat area by D. S. Bhattacharji. The lower grade of metamorphism of the Sakolis, it is suggested, may be due to their having undergone retrograde metamorphism.

(c) *Chhota Nagpur.*

The Archæans of Chhota Nagpur are distinguished by the presence of large iron-ore bodies (the Iron-ore series) and have

The Iron-ore series

attracted much attention of late years. This series is a thick and widespread group of metamorphic clastic sediments grading upwards in North Singhbhum to tuffs and lava flows. Three thousand million tons of high grade workable iron-ores, mainly hæmatitic, is proved in this series (25). The ultimate origin of the iron-oxide concentrates in the series is yet much debated—chemical, organic, sedimentary and volcanic origins being suggested by different observers. Perhaps no one explanation applies to all the deposits. J. A. Dunn has studied the Iron-ore series and associated Archæans of Singhbhum (11, 12) in detail and thrown light upon the various problems of economic minerals, petrogenesis and ore-genesis which these rocks present. Dunn recognizes no earlier rocks, sedimentary or igneous, in Singhbhum than the Iron-ore series, which is a group of phyllites, shales and quartzites, overlain by tuffs and basic lavas, the more strongly folded portions of which show every grade of metamorphism from schists of the epizone to gneissic rocks of the hypozone. M. S. Krishnan has lately published a memoir (26) in which he discusses the correlation of the Archæans of the area to the south-west. He distinguishes a group of basal phyllites with gondite, marble and dolomite (Gangpur series) from the overlying Iron-ore series, which he regards as of Upper Dharwarian age. In Sir L. L. Fermor's scheme of correlation between the Archæans of different parts of India (14) he uses the Gonditic rocks, with marbles as confirmatory evidence, as a datum-line on the assumption that the manganese-ores and marbles mark one single stage of deposition in the Archæans. On this ground he correlates the Gangpur series with the Sausars and the Iron-ore series with the Sakolis.

In the Bastar State (south-east of Central Provinces), H. Crookshank differentiates three Archæan groups—andalusite-gneiss and quartz-schists, a group of hæmatitic-quartzites, and quartzite. A part at least of the Bastar sequence is probably correlated to the Iron-ore series of Singhbhum.

L. A. N. Iyer has recently studied the gneissose granite of Bengal. Much of this granite is foliated, but coarse-grained and porphyritic types are present. Clear evidence of intrusion into schists is furnished by the hybrid injection-gneisses produced. Tourmalinization of the schists is a feature of the intrusion.

(*d*) *Mysore State.*

B. Rama Rao in an important paper (37) has lately controverted the view of W. F. Smeeth and P. S. Iyengar, which had prevailed since 1910, that the Dharwar schists which form the basement complex of a large part of the Mysore territories were *all* of igneous origin. He has brought forward evidence of ripple-marks, current-bedding and other structural characters of shallow-

water facies of sedimentation in the schistose rocks of widely separated areas to demonstrate the sedimentary origin of the Mysore Archæan complex of many parts of the State ; their inter-bedded conglomerates, which were supposed to be autoclastic, have in several cases been found to be of sedimentary deposition.

The basement of the Mysore Archæans is an igneous complex consisting of acid and basic intrusions, deformed lavas and tuffs. Recent investigations on the granitic complex of Mysore disclose only two eruptive epochs, not four as hitherto believed. The types differentiated as 'Champion gneiss' and 'Peninsular gneiss' are found to be the modified product of consolidation of a single eruptive magma : the older belief that the Peninsular gneiss was the basement rock on which the Dharwars were deposited has within recent years been shown to be untenable.

The Dharwars of the type area and of Mysore are believed to be correlatable to the Champaners of Bombay and the Aravallis of Rajputana.

Classification of the Archæans

Fermor is now engaged upon a comprehensive description of the Archæans of the Indian Peninsula. He proposes to divide the Archæans of the Peninsula into 15 provinces based on their petrological characters (14). The whole Archæan terrain is first broadly divided into two regions—the *Charnockitic* and the *Non-charnockitic* ; these major regions are further subdivided into a number of provinces grouped under (1) the Iron-ore provinces, (2) the Manganese-ore-marble provinces, and (3) Igneous provinces. In establishing these divisions and their inter-correlations, he makes use of the following criteria :—

(1) Stratigraphic sequence.
(2) Structural relationships, unconformities, periods of folding, etc.
(3) Relationship to igneous intrusives.
(4) Associated ore-deposits of epi-genetic origin.
(5) Lithological composition.
(6) Chemical composition.
(7) Grade of metamorphism.
(8) Lead and helium ratios.

Besides the papers mentioned, there have been some interesting contributions on the several Archæan petrological types by A. L. Coulson, P. K. Ghosh, and by a few University students.

(e) *The Himalayan Archæans.*

There are no Archæan outcrops between the northern edge of the Peninsula and the inner part of the Himalaya ; the few straggling hillocks of Kirana and Sangla, composed of Malani rhyolites (Purana), may, however, have a substratum of the Aravallis. The Himalayan

Archæans are largely composed of metamorphosed sediments—the Salkhala series of Kashmir, the Jutogh series of the Simla Himalayas, the Vaikrita series of Spiti, and the Dalings of the Sikkim Himalayas; but few outcrops of undoubted Archæan granites or gneisses are definitely known. The large bodies of these rocks, to which the name of 'Central Gneiss' was given and which were tacitly assumed to be Archæan, were long ago proved to be later intrusive granite by McMahon. Recent work has confirmed this view and proved extensive masses of granite to be of probable Cretaceous or Eocene age in the Everest area (Heron), and in the Great Himalaya range in Kashmir (Wadia).

The unconformable relationship of the Himalayan Archæan sedimentary formations to the Puranas has been proved in Kashmir (44, 46). In this area the conformable passage of the Purana slates into fossiliferous Cambrian rocks, containing a strongly provincial fauna of trilobites and brachiopods, has been demonstrated by Wadia (46). Large tracts of Hazara, Gilgit and of the Zanskar range are covered by the Salkhalas, often converted into para-gneiss, the great massif of Nanga Parbat (26,620 ft.) being built wholly of these rocks together with intrusive granites of later ages (45). It is possible that future research will show that the central axial range of the Himalaya (the Great Himalaya range) is largely constituted of the Archæan sediments of the type of Rajputana, Dharwar, and Singhbhum Archæans, and that this range represents the basement of the ancient peninsular rocks on which the Tethyan sediments were laid down in the Himalayan geosyncline. It thus denotes the Himalayan protaxis.

III. The Gondwana System.

The progress of geological investigation during the last two decades has not much altered the basic ideas regarding this system of continental deposition ranging from Upper Carboniferous to Lower Cretaceous, or the concept of the Peninsula being a segment of a large southern continent, 'Gondwanaland', which joined up many of the peninsulas of the southern hemisphere from Australia to South Africa or even South America. In the matter of classificatory details, of fresh discoveries enriching fossil floras and faunas of the period, and in the precise fixing of the age of the basal boulder-bed as Uralian, however, there has been a marked advance of recent years.

Association with marine strata

A most interesting discovery in Gondwana geology was reported by K. P. Sinor in 1921—a temporary and localized invasion of the Productus Sea of the Salt Range into the heart of the Peninsula. This marine transgression has left a few feet of limestone crowded with *Spirifera* and *Productus* at the base of the Barakar stage of the Lower Gondwana Coal-measures at Umaria, Central India.

The occurrence of *Eurydesma cordatum* and the typical Lower Gondwana fossil plants *Gangamopteris* and *Glossopteris* in sandstones directly overlying the glacial Boulder-bed of the Salt Range, and considerably below the horizon of the Lower Productus limestone containing the Fusulinid, *Parafusulina kataensis* (a Permian form), places the Boulder-bed at the top of the Moscovian or at most in the Uralian. Over 500 feet of sandstones and shales containing intercalations bearing fossil fronds of genera belonging to the *Glossopteris* flora of the Talchir horizon separate the two zones.

While there is general agreement regarding the classification of the Lower Gondwanas and the horizons of the principal series and stages are now more or less fixed, there is a great deal of disagreement regarding the succession of the main divisions of the Upper Gondwanas. Cotter places the Parsora stage in the Lower Gondwana, Fox assigns it a place high up in the Upper Gondwanas (Upper Jurassic), while Prof. B. Sahni regards it as Rhætic or still older and puts it near the base of that division. Wadia finds in this a justification for retaining the Middle Gondwana division originally instituted by Feistmantel. Cotter assigns the Jabalpur beds to the Upper Neocomian (if not a newer stage, Aptian)—a horizon above Umia beds, while Fox (18) and Crookshank (10) regard them as ranging between the Middle and Upper Jurassic and older than the Umia stage. The age of the Rajmahal series has lately come under question.

Age of the East Coast Gondwanas

The discovery of new ammonite fossils from coastal Upper Gondwana beds at the mouths of the Godavari and Kistna rivers by L. A. N. Iyer, and their identification by L. F. Spath as Upper Neocomian forms *Holcodiscus* cf. *perezianus*, *Hemihoplites* (?) *borrowæ*, *H. beskidensis*, *Lytoceras*, *Gymnoplites simplex* and species of *Pascœites* greatly alters the stratigraphical position of these beds. As the fossil flora of the coastal Gondwanas is very nearly identical with that of the Rajmahal series of north-west Bengal, the latter may be now regarded as of Neocomian age and newer than the Umia stage. This is not surprising, for in 1932 Sahni in an important paper (40*a*) had drawn attention to the occurrence of angiospermous wood from this deposit—*Homoxylon rajmahalensis* (a Magnoliacæ plant), and had clearly stated that the fossil indicates a higher horizon than the Jurassic and that the presumed Jurassic age of the Rajmahal deposit should not be accepted without reserve.

A land-bridge between Gondwana- and Angaraland

The idea of a northward migration of Gondwanaland plants to the northern continent of Angaraland was suggested forty years ago by the discovery of some marked affinities of Russian and Siberian fossil plants with the *Glossopteris* flora of India. Zalessky, Seward and Sahni all advocated the view of intermigration, and Zalessky suggested an isthmus con-

necting the two continents across the Himalayan sea. In 1926, Sahni suggested that the most obvious route must have been through Kashmir, and that even Kashmir was a southern outpost of Angara-land. Field work in Kashmir by Wadia during 1928–34 has proved that during the greater part of the Silurian-Middle Carboniferous interval dry land existed in N.W. Punjab, Salt Range, Hazara, and Kashmir, to as far north as the Pamirs (46). In all these areas either the Cambrian or the Silurian strata are overlain by the Upper Carboniferous, commencing with the Panjal Volcanic series, with a pronounced and widespread regional unconformity. This mid-Palæozoic land-mass of Kashmir must have functioned as a land-bridge between the two continents during pre-Upper Carboniferous ages. Wadia further states that even during the Upper Carboniferous, the Kashmir part of the Tethys must have been studded with an archipelago of volcanic islands which may well have permitted an interchange of land plants.

Classification

A tentative classification of the Gondwana system which may find general support is tabulated below :—

Upper Gondwana	Rajmahal stage and Coastal Gondwanas ..	.. Aptian ?
	Umia Plant-beds	.. Tithonian
	Jabalpur stage	.. Upper Oolite
	Chaugan stage	.. Lower Oolite
	Kota stage ..	.. Lias.
	Maleri stage ..	.. Rhætic
	Parsora stage ..	.. ? Middle Trias (? Upper Trias).
Lower Gondwana	Panchet stage ..	Upper Permian
	Raniganj stage	Middle Permian
	Barakar stage ..	Lower Permian
	Karharbari stage	Uralian
	Talchir Boulder-bed	Upper Carboniferous.

Gondwana climates

There is evidence of some marked and rapid climatic changes in the rocks of the Gondwana system, though no generally accepted sequence has so far been worked out. The data on which conclusions regarding oscillations of climate are based are the boulder-beds, or till, resting on an ice-planed surface in many parts of India during the Talchir stage, contemporaneous with the Permo-Carboniferous glaciation of Australia, South Africa and South America ; the occurrence of thick seams of coal, up to 60, 80 and even 100 feet, in the next succeeding Damuda series ; the presence of erratic or exotic blocks in fine-grained sediments ; and the presence of fresh, undecomposed felspar in the sandstones of the overlying series.

The Upper Gondwana sandstone and clay are notably ferruginous and red coloured, with this is combined an absence of any carbonaceous matter—symptoms, according to some authorities, of an arid or semi-desert climate.

Geographical Relations of Gondwanaland

Both the supporters of Wegener's theory of Continental Drift and its opponents have looked for evidence in support of their respective views in the later geological history of the different units of Gondwanaland. The separation of the now discrete units of the once continuous southern continent of the Palæozoic (*Pangea*) is brought about, according to one view by the drifting away (e.g., north-easterly drift) of India from Africa; and by the fragmentation and foundering of large segments of the land under the oceans, according to the other.

Faunal and floral relationship

Palæontological facts clearly show that the Indian Mesozoic systems from the Trias to the Danian stage of the Cretaceous are more closely related to Madagascar and South Africa than to Europe. Only at the end of the Cretaceous the fauna enclosed in the Infra- and Inter-trappean beds shows relationships to Sind, Persia and further west. In an important paper on the geographical relations of Gondwanaland, the eminent American geologists, Profs. Schuchert and Bailey Willis, present geological and biogeographic evidence which strongly supports the existence of land-bridges or isthmuses of the nature of Cordilleras, rather than a continuous land mass, connecting Brazil, Africa and India, from the pre-Cambrian to the end of the Cretaceous. A. L. du Toit, on the other hand, supports the hypothesis of continental drift in a paper on the geological comparison of the sedimentary sequence in South America with South Africa.

After an examination of the available palæobotanical data and especially the case of the two originally very distinct floras (the *Glossopteris* flora of India and Australia and the *Gigantopteris* flora of China and Sumatra) now seen in close juxtaposition and even dovetailed with one another, B. Sahni concludes that they are not enough to prove the drifting apart of the different portions of Gondwanaland but that we are compelled to agree that drift movements of large magnitude elsewhere have brought into juxtaposition continents once separated by wide oceans. The evidence from the distribution of fossil Mesozoic lamellibranchs, cephalopods, and reptiles in India and Africa is likewise inconclusive on the matter of drift, although parallelisms have been established between several elements of the Cretaceous and Jurassic faunas of these two areas.

Recent contributions

Professor B. Sahni has made important contributions to our knowledge of the Gondwana flora in a series of papers since 1920 (40). He deals with the various aspects of the succession of fossil floras,

their climatic, physical and evolutionary background ; the employment of improved technique of investigation at his laboratory at the Lucknow University has resulted in much additional information regarding several old species, while the geological ranges of several others have had to be revised. Dr. C. S. Fox has made a comprehensive systematic restudy of the Gondwana system and its related formations, their relative chronology, classification and the natural history of Indian coal deposits and the total reserves of coal distributed in the different coalfields of the country (17, 18). Coal, one of the most important mineral products raised in the country, is derived 98 per cent from the Lower Gondwanas. Its output has increased fourfold since the beginning of this century.

Indian Coal reserves

But the total reserves of good grades of this fuel as estimated by Dr. Fox is less than 5,000 million-tons. A warning note has therefore been sounded for the conservation of the better-grade coal for metallurgical uses and for more scientific and economical methods of working of the thick seams in which much of the Gondwana coal is found. Coal mining in India has so far been less dangerous, because of the less common association of highly explosive gases (marsh-gas) with coal as compared with European coalfields. There are, however, special difficulties associated with the working of the thick seams, only a few hundred feet from the surface, and fires and subsidences have created problems of their own.

IV. The Deccan Trap.

The plateau basalts of the Deccan which to-day occupy 200,000 square miles and have a vertical extension of 6,000 feet, constitute one of the most interesting types of igneous activity—the flooding of the vast Mesozoic peneplane of central and western India by an undifferentiated primitive basic magma, erupted mainly through fissures and not through volcanic vents. A great deal of petrographical work carried out of recent years, has brought to light many facts in regard to the origin of rock-types and processes at work in the lava flows during and after the eruption. Compared with the vast bulk of horizontally bedded basalts and dolerites of uniform composition, the areas showing magmatic differentiation are but few and restricted, so far as present investigation has gone, to the north-western edge of the outcrop of the plateau basalts, extending from Bombay northwards through Kathiawar and Cutch. A great variety of rocks of acid, intermediate, basic and ultra-basic composition has resulted from this segregation, some of them markedly alkaline.

The detailed petrography of the Deccan trap is based on the work of Sir L. L. Fermor on the cores of a boring at Bhusawal (15) which penetrated 29 horizontally bedded flows of an aggregate

thickness of 1,171 feet, the thickness of individual flows varying from 5 ft. to 97 ft. His descriptions of the rocks encountered in this thick succession are regarded as typical of the greater portion of the flows of the Deccan trap, the predominant type being a basalt of specific gravity 2·91, consisting essentially of laboradorite (Ab_1 An_2), enstatite-augite, glass and iron-ore, olivine occurring in the majority of the flows but not universally. A host of secondary minerals are found as alteration-product, of the glassy base or of some primary minerals of the rock, e.g., palagonite, chlorophæite, celadonite, chabazite, iddingsite, delessite, or as late secretions filling the amygdaloidal cavities of the lava—zeolites, chalcedony, opal, delessite, calcite, quartz and lussatite. Fermor has shown that some ultra-basic modifications of the basalt may have originated by gravity differentiation, i.e., by the sinking of olivine and basic felspar phenocrysts to the base of thick lava-flows which remained fluid enough after eruption for a longer period than other flows. This, however, is not generally the case, though it may have originated in special cases.

Petrography of the traps

Areas which offer the best illustrations of advanced differentiation are the Girnar hill of Kathiawar and the Pavagarh hill near Baroda ; the former area is described by M. S. Krishnan and K. K. Mathur, and the latter area by L. L. Fermor and A. M. Heron. At the Girnar focus of eruption are clustered such diverse types as quartz-porphyry, syenite, monzonite, diorite, andesite, olivine-gabbro, lamprophyre, limburgite, obsidan, rhyolite and pitchstone. These types are not effusive but are intruded into the normal Deccan trap basalts of the Girnar forest, the dome-like mass of Mt. Girnar being considered as having resulted from an ascent of the plutonic magma.

Their magmatic differentiation

The rhyolite of Pavagarh hill is now proved by Heron to be a part of the bedded basalts of the area, a flow of acid composition along with doubtful tuffs, etc. capping the summit of the solitary hill rising from the plains of Baroda.

W. D. West thinks that the more basic types, such as limburgite and ankaramite, interbedded with the normal basalts in Kathiawar, did not orginate by the sinking of the heavier minerals of basalt, but that the basic types were differentiated prior to their extrusion.

The acid intrusives into the Deccan trap show a more extensive distribution than the basic, though their total volume is quite insignificant in comparison with the bulk of the plateau basalts. The ultra-basic rocks, e.g., olivine-gabbro, oceanite, ankaramite, limburgite, etc., occur in dykes and small stocks.

Crookshank has observed interesting field relations of the Deccan traps with the associated fissure-dykes traversing them in the northern slopes of the Satpura (10). A plexus of dykes and sills of dolerite permeates and ramifies through the underlying and surrounding Upper Gondwanas in a manner suggesting that the dykes were the feeders of the eruptions. Similar dykes running for distances are a common feature along the periphery of the Deccan trap outcrop.

The Age of the Deccan traps

The age of the Deccan trap is its most important problem and interest in it is revived of recent years by the steady growth of palæobotanical evidence in support of an Eocene age rather than the Middle or late Cretaceous age which the stratigraphic evidence and field relations of the traps to the formations below and above them supported. Matley's work in 1927 on the infra-trappean Lameta beds of Jubbulpore indicated a Middle Cretaceous age for the traps, based on geological relationships and on the affinities of the Dinosaur fossil remains, while the unconformity between what were thought to be the topbeds of the traps and the overlying Nummulitic limestone of Surat has pointed to their infra-Eocene position since Blanford's days, an inference with which Dr. Fox concurs. The determination of age based on the radio-active property of basalts is in progress, the few results so far to hand, according to V. S. Dubey, pointing to a lower Tertiary age. But the most positive test of Eocene age is, according to Prof. B. Sahni, supplied by the rich flora of the inter-trappean beds of Nagpur-Chhindwara. These beds contain an abundance of fossil palms with numerous *Nipadites*, a characteristic Eocene genus, and fertile specimens of *Azolla*, a modern genus of floating water-ferns, of which all the previous fossil records are post-Cretaceous. Sahni thinks that the Deccan Inter-trappean flora finds its clearest affinities with the London clay flora. These conclusions are supported by the recent discovery by L. R. Rao, S. R. Rao and K. S. Rao, of *Chara*, *Acicularia* and numerous foraminifera from Inter-trappean beds near Rajahmundry, which also contain well-preserved shells of a form closely allied to *Cardita beaumonti*, as pointed out by the late Prof. H. C. Das Gupta.

London clay Flora and Eocene Fishes

Some fossil fishes from the *infra*-trappean Lameta series of the Central Provinces determined by Sir A. Woodward indicated Eocene affinities. Dr. S. L. Hora, who is examining some fresh discoveries of fossil fish from the *inter*-trappeans of the Central Provinces, has also ascribed an Eocene horizon to these remains. He recognizes in these scales the representatives of an osteoglossid genus *Musperia*, and several members of the genus *Clupea* and some Percoids, members of which date back as far as the Eocene, but not earlier.

V. The Salt Range.

The fullness of the geological record, the structural complexity, and the many tectonic problems presented by this 100-mile line of escarpments—the classic ground of Indian stratigraphical geology since 1870—invest these mountains with high importance in interpreting the geology and tectonics of Northern India. As a result of the investigations of many able geologists during the last sixty years, the stratigraphy of the mountains was fairly fully worked out. However, the great tectonic complexities arising through numerous inversions and thrust-faults which have brought the highly characteristic Saline series, from which the mountains take their name, into juxtaposition with almost every other formation of the range, have made the question of the correct position of that series a very vexed and controversial one. Since 1928 detailed and concentrated field work carried out by E. R. Gee is yielding results which bid fair to solve this question of the age of the salt, concerning which almost every observer had propounded a theory, and to put the tectonic interpretation of this faulted array of cliffs, abruptly rising from the plains of western Punjab, on a satisfactory basis. Gee's memoir on the Salt Range is under preparation and is expected to appear in the near future.

The position of the Saline Series

The most interesting constituent of the Salt Range, occurring in prominent exposures along the foot of the Range, is the Saline series. It consists of an upper stage of massive gypsum, with flaggy dolomites and bituminous shales ; a middle stage of red marl, with thick seams of rock-salt, attaining a total thickness of 600 feet ; and a lower stage of marl, gypsum and dolomite, several hundred feet thick. The base is nowhere seen. It is overlain by Cambrian (or ? pre-Cambrian) strata in the eastern part of the range and often by the Upper Carboniferous Talchir boulder-bed in the western. Its relation to the Eocene is anomalous in all parts of the range. At some localities it is brought into juxtaposition with the Siwaliks. At Mari Indus and at Kalabagh, on the east and west sides of the Indus respectively, a similar sequence of rock-salt, marl and overlying gypsum and dolomite is met with. Here, the structure is extremely complicated though on the whole the saline deposits are closely associated with Siwalik beds. Tracing the stratigraphy north of Kalabagh, a faulted anticline of Siwalik strata runs up the Luni Wahan to link up with the salt and gypsum deposits of the Kohat salt region near Shakardarra—a distance of only 18 miles from Kalabagh. About halfway between these two places, inliers of salt-bearing marl, gypsum, etc., crop out along the axis of this faulted anticline, whilst at Shakardarra, Upper Laki limestones and clays intervene between the saline deposits and the Siwaliks. There are, therefore, good grounds for regarding the Kalabagh and Mari salt deposits as equivalent to those of Kohat.

To the north and west of these Shakardarra exposures the Kohat salt is exposed in a number of anticlines, e.g., at Jatta, Bahadur Khel and Malgin.

A subject of long controversy

In the original geological survey in the seventies, the existence of large tectonic thrusts being unrecognized in those days, it was tacitly assumed that the salt and associated deposits of Kohat and of the Salt Range were of different geological ages, the former Eocene, the latter Cambrian or pre-Cambrian. A long period of controversy followed and at least five different theories were evolved to explain the age and origin of the salt and gypsum. Between 1907 and 1920, Dr. Koken, Sir Thomas Holland and Sir Edwin Pascoe, however, suggested that the infra-Cambrian position of the salt was adventitious and due to extensive inversion and thrust-faulting, but this view did not meet with general acceptance. In 1924, D. N. Wadia and Lt.-Col. L. M. Davies proved on stratigraphical and palæontological grounds that the saline series at Kohat was a part of the local Laki series, the gypsum being a transformed Nummulitic limestone directly above the Ranikot-Laki unconformity. This Lower Eocene age for the Kohat gypsum was later confirmed by Gee, who discovered fossil fishes in the gypsum stage at Malgin. The equivalence of this with the Cis-Indus salt of the Salt Range, however, though indicated, was not proved. More recently, Dr. G. de P. Cotter (7), whilst agreeing to a Lower Eocene age for the Saline series, suggested that it was intruded southwards in the Salt range area. Since 1929 Gee has collected evidence which strongly indicates that the foraminiferal limestone at the top of the Nummulitic limestone (Laki series) denotes the stratigraphical horizon of the gypsum and associated beds of the Saline series. In some clear sections he has observed the lateral passage of the one into the other ; the change of grey and white limestone passing into dark foetid limestone with subordinate gypsum, and of this into massive gypsum, 300 feet thick, being accomplished within a few hundred yards. These critical sections, 4 to 6 miles south of the Indus, at the western end of the Salt Range, have been examined by Dr. Heron, E. S. Pinfold, P. Evans and other geologists who have confirmed Gee's interpretation of the lateral transformation. E. S. Pinfold, L. M. Davies, P. Evans and E. R. Gee have established a correlation on stratigraphical grounds between the Kohat Eocene sequence and that of the Chharat area of Attock and parts of the Salt Range. There is, therefore, good reason to conclude that the Nummulitic sequence of the Kohat region is *in situ* and normal,

The post-Eocene Nappe

while thrusts of immense dimensions (*nappes*) must be postulated to explain the present infra-Palæozoic position of the Saline series in the Salt Range area. Gee concludes that the *nappe* involved in this movement was post-Nummulitic and pre-Siwalik in age, that it thrust the Eocene Saline series underneath the Cambrian rocks

and brought about a bodily movement of the Eocene, Mesozoic and older rocks towards the south in the Salt Range proper and towards the east in the trans-Indus extension of the range, the horizontal displacement being a maximum of at least 20 miles. A second period of tectonic disturbance commenced in the Mid-Pliocene time and continued into Sub-Recent, the dominant direction of pressure being from the north. The hidden Archæan massif of the Punjab foreland, the existence of which is indicated by geodetic observations and the presence of a few isolated hillocks of Archæan or Purana rocks, impeded the southern advance of the Salt Range *nappe* and gave to this range its sinuate and indented alignment.

The stratigraphy of the Cambrian, Upper Carboniferous, Permian, Lower Trias, Jurassic, Cretaceous and a fairly complete sequence of the Tertiary of the Salt Range has been worked out, though for the precise age and correlation of the various stages and series much palæontological work remains to be done on the large collections of fossils that have been made during the last eight years, particularly from the Permo-Carboniferous, Trias, Jurassic, Cretaceous and Eocene. There are three major unconformities in the Salt Range succession: (1) the most significant, between the top of the Cambrian and the base of the Permo-Carboniferous—the Talchir boulder-bed. This is the most widespread regional unconformity of north India, as already referred to on page 95 (46). (2) At the base of the Nummulitic series (Ranikot series) a ferruginous pisolite (a laterite capping an old land-surface ?) is found resting either on the Upper Palæozoic or on various Mesozoic horizons. The Cretaceous is of restricted development, being found at a few localities at the west end of the range. (3) A less prominent unconformity between the Nummulitics and the basal beds of the Siwalik, the Murree series being here, in a large measure, absent or scantily developed. The base of the Upper Carboniferous, commencing with the glacial boulder-conglomerate, is an important datum-line in the geology of India—in the Peninsula as well as in the extra-Peninsular mountains. It marks the beginning of the Tethyan (Aryan) Era of marine geosynclinal sediment in the Himalaya and of the system of continental coal-bearing deposits in the Peninsula (Gondwana system). The marine period of the Salt Range, ushered in now, has given rise to such a full sequence of fossiliferous Permian strata that the term Punjabian is proposed for this most remarkable succession. An added interest is the commingling of Lower Gondwana *Glossopteris* flora with the lower stages of the Productus limestone, crowded with a rich brachiopod fauna, and also almost immediately above the Talchir boulder-bed. Magnificent collections of fossil brachiopods, corals, echinoids, cephalopods, polyzoa,

Major unconformities in the Salt Range

Faunal richness of the Productus Limestone

fusulines, etc. have been made, and are in course of investigation by Dr. F. R. Cowper Reed. A large representative collection of the fauna has been sent to Prof. Schuchert of Yale University. The flora is being examined by Prof. B. Sahni.

Striking evidence of very recent earth movements in the Salt Range is obtained not only in steeply tilted post-Siwalik (Mid-Pleistocene) sands and conglomerates but also in the occurrence of relatively modern lenticles and beds of sediments, formed originally at the foot of the scarp, and caught up and intercalated within the plastic saline series during the late tectonic movements. The inclusion of these sub-Recent beds has further complicated the problem of determining the age of the Saline series.

VI. Classification of the Tertiaries.

N.-W. India

The Tertiaries of Northern India and Burma include a thickness of some 40,000–50,000 feet of beds, and during the period under review this vast accumulation of sediments has received much attention, partly on account of the rich fauna found in a few localities—for example the mammalian remains of the Siwalik and Bugti Hills, and the invertebrate fossils of the Mekran Coast and Burma, and partly because of the association of oil and coal with Tertiary strata. In the region including the Punjab, Kashmir, and N.-W. Frontier Province, the work of G. de P. Cotter, D. N. Wadia, E. R. Gee, and other members of the Geological Survey of India, and also of E. S. Pinfold, R. v. V. Anderson and other petroleum geologists has supplemented the palæontological work of G. Pilgrim and Col. L. M. Davies, and has thrown much light on all the members of the Tertiary succession. The work of Pinfold in particular has led to a better understanding of the relationships of the Eocene with the higher beds.

Assam and Burma

In Assam, a large area has been surveyed by the geologists of the Burmah Oil Company and a summary of the stratigraphy has been published (13) by Percy Evans. This work has enabled a classification to be made for a very great thickness of almost unfossiliferous rocks, and has established the presence of a large previously unsuspected gap in the succession corresponding to the break between the Eocene and the Miocene in N.-W. India. Many papers on the neighbouring Burma Tertiaries have appeared in the Geological Survey Records and there have been others in the literature of the oil industry.

Sedimentary Petrology

During the past few years an extensive study of the heavy minerals of the Tertiary rocks has been made, notably by the Assam Oil Co. petroleum geologists under the direction of P. Evans, and it

has been found that over very wide areas, the broad features of the accessory mineral suites of successive subdivisions of the Tertiaries remain the same, and that over smaller, but still quite considerable, areas comparatively minor details show a high degree of correspondence. This has proved very helpful in correlation problems in Assam and may be expected to have a wide application elsewhere in India (13).

VII. Tectonics and Stratigraphy of the Himalayas.

Large unsurveyed areas of the Himalayas

In spite of the large blanks still existing on the geological map of the Himalayas, representing nearly three quarters of the total area of the Himalayas, there has been during the period covered by this review considerable advance in our knowledge of the geology of these mountains, especially in discovering the broad lines of their structural plan. Except for the immediate neighbourhood of Mount Everest, geologically reconnaissanced by successive Mount Everest Expeditions, only two regions, Hazara-Kashmir and Simla-Chakrata, have been mapped in some detail; the mountains of Garhwal and Kumaon, after the pioneer survey of the last century, have received only occasional attention from geologists; while the entire block of the Nepal-Assam Himalayas except for small areas in Sikkim, still remains a *terra incognita*. However, the policy of the Geological Survey of India in concentrating its available resources on two or three critical areas and of taking advantage of any opportunity for traverses in new areas has borne fruit, for the results so far obtained in stratigraphy and tectonics disclose a unity of structure and constitution for the whole of this mountain system from the Indus to the Brahmaputra. Data are slowly accumulating which tend to show that the baffling complexity of structure and diversity from area to area of the Alps, though encountered in a few local patches, are not met with in the same degree in the Himalaya, a fact which, if substantiated by further work, will enable a complete synthesis of Himalayan geology and orogeny to be built up in the near future.

Himalayan Stratigraphy—Correlations

Medlicott in the Kumaon and Middlemiss in the Kashmir Himalayas in 1910 securely laid the foundations of the stratigraphy of the Himalayas. The total absence of fossils in the Simla Himalaya introduces great difficulty and uncertainty in correlating even the broad divisions of strata, but of late years careful study of relative metamorphism and structural relations of thrust-planes and unconformities have enabled the natural order of superposition of strata to be established more or less parallelly with the fossiliferous systems of Kashmir. The following table of

correlations expresses the extent of parallelism prevailing in different parts of the Himalaya, so far as the Palæozoic group is concerned :

	KASHMIR.	HAZARA.	SIMLA.	SIKKIM.
Trias ..	Upper Trias .. Middle Trias. Lower Trias.	Upper Trias	?	Trias.
Permian ..	Zewan Series—(*Productus* limestone). Panjal Volcanics ..	Sirban limestone. Panjal volcanics.	Krol, and Shali limestones. Infra Krol.	Permian limestone.
Carboniferous	*Gangamopteris* beds Agglomeratic. Slate (Talchir). *Fenestella* Series. *Syringothyris* limestone. (Up. Tanawal)	Boulder-bed (Talchir). Unconformity	Blaini series (Talchir).	Lower Gondwana ? Boulder-bed.
Devonian ..	Lr. Tanawal series Muth quartzites.	Lr. Tanawal	Deoban limestone. Jaunsar series Nagthat series.	? Deoban
Silurian ..	Silurian ..	....	....	....
Cambrian ..	Up. Cambrian. Md. Cambrian. ? Dogra slate ..	Hazara slate	Simla slate ..	Baxa series.
Algonkian ..	Undifferentiated Purana.	Undifferentiated Purana.	Chail ..	Daling series.
Archæan ..	Salkhala series ..	Salkhala series.	Jutogh series.	Archæan.

Stratigraphic Zones or belts

The Himalayas have been divided into 3 longitudinal stratigraphical zones, an outer or *Sub-Himalayan zone*, composed of Tertiary rocks ; a central or *Himalayan zone*, composed of crystallines and unfossiliferous slaty sediments constituting the line of high snowy peaks ; and a northern or *Tibetan zone* composed of fossiliferous marine sediments ranging from Cambrian to Eocene (23). It is probable that the middle Himalayan zone denotes the central geanticline within the main Himàlayan geosyncline. This axis (the Great Himalaya range) passes close on the southern shore of the Tethys in the Eastern Himalaya with the result that the whole

Tibetan zone is confined to the north and there is but little of marine Palæozoic and Mesozoic sediments on the Indian side of the axis, whereas it occupies a more central position in the Western Himalaya of Kashmir and Hazara where the Tibetan zone is not confined to the north of the Great Himalayan range but is found in detached patches on both sides of the axis. The unfossiliferous sedimentary systems of Simla-Chakrata may be regarded as detached outliers of the Tibetan formations of Spiti, though their total lack of fossils is still an inexplicable circumstance. It is also possible that some of these systems, the older ones at least, are the congeners of the Peninsular Purana formations.

The Himalayan granite

Granite enters largely into the composition of the central range of the Himalayas and builds the greater part of the line of high snowy peaks from Kashmir to Assam rising above 20,000 feet. Three kinds of granite have been recognized; the most common is biotite-granite, often a finely foliated gneiss, augen-gneiss, or porphyritic gneiss, according to its position and relation to the sediment into which it is intruded. The next common granite is hornblende-granite with conspicuous sphene. The third variety is tourmaline-granite occurring in bands and as minor injections into biotite-granite. It is probable that both in respect of age and origin the three granites do not differ much and may have originated by differentiation from a common acid magma. The belief that most of the Himalayan granites are of Tertiary age is receiving confirmation. Large granitic areas of the Eastern Himalaya and Tibet are regarded by Heron to be Cretaceous or post-Cretaceous. The hornblende-granite of the Astor-Deosai mountains of north Kashmir, covering several hundred square miles, has been found by Wadia to be intrusive into the Cretaceous series containing *Orbitolina*. G. H. Tipper found the Jurassic rocks of Chitral penetrated by the biotite-granite. McMahon, who first proved the intrusive origin of gneisses of the central axial zone (which were at first called 'central gneiss' and regarded as Archæan), believed the granite to be of Eocene age, the intrusions being approximately coincident with the disturbances to which the elevation of the Himalaya is due. The postulated Archæan age of the Himalayan granite of most localities, especially in the Kashmir and Hazara areas, remains to be proved.

(a) *The Kashmir Himalaya.*

Geological field work during the last twelve years by D. N. Wadia in Kashmir, W. D. West in Simla and J. B. Auden in Garhwal throws light on the type of mountain structure present in the middle Himalayas. The structure of the inner Himalayas has not yet received such intensive study as that which has so far unravelled the inner architecture of the Alps, and it is not possible to say anything regarding the structure of these ranges except

in general terms. East of Kumaon no systematic geological work has yet begun. The evidence so far obtained, however, tends to show that large areas of the Western Himalaya possess a rather less complicated type of tectonics, and the piles of nappes, their complex refolding, digitations and involutions such as those to which modern theory ascribes the formation of the Swiss Alps, have been less commonly observed in the Himalayas. The thrusts in the Himalaya of the Kashmir region at least, that have driven sheets of older rocks over newer, recall rather the thrust-planes of the Scottish Highlands. There is, however, some amount of folding and warping of the thrust-planes as observed by West in the Simla Hills and by Auden in Garhwal.

Tectonically the Kashmir Himalaya consists of three structural elements (44) according to Wadia :—

Three tectonic elements of Kashmir mountains

(1) the tongue of the *foreland*, its peneplaned surface being buried under a thick cover of Murree (Miocene) sediments ;

(2) a belt of *autochthonous*, mainly recumbent, folds consisting of rocks ranging in age from Carboniferous to Eocene, thrust against and over the foreland covered under the Murree series (Murree thrust). Southward overfolding and thrusting, with a dominant north-east dip, is the prevalent structural tendency of this region ;

(3) the *nappe zone* of inner Himalayan rocks, which has travelled far along a horizontal thrust (Panjal thrust) so as to lie fitfully sometimes against a wide belt of the autochthone, at other times almost against the foreland. The Kashmir nappe is composed mostly of pre-Cambrian sediments (Salkhala series) with a superjacent series (Dogra slate), forming the floor of the Himalayan geosyncline that has been ridged up and thrust forward in a nearly horizontal sheet fold. On this ancient basement lie synclinal basins containing a more or less full sequence of Palæozoic and Triassic marine deposits in various parts of Kashmir. The latter are detached outliers of the Tibetan marine zone, which in the eastern Himalaya is confined to the north of the central Himalayan axis.

Two thrust-planes in the Pir Panjal

The most important tectonic feature of this region is the occurrence of two great concurrent thrusts on the southern front of the Himalaya, delimiting the autochthonous belt, which have been traced round the re-entrant from the Hazara border to Dalhousie, a distance of 250 miles. Of these two thrusts, the inner one (Panjal thrust) is the more significant, involving large scale horizontal displacements. The outer,. the Murree thrust, shows greater vertical displacement and is steeper in inclination but has an equal persistence over the whole region. In its geological structure, the autochthonous zone between these two thrusts is composed of a series of inverted folds of the Eocene (Nummulitic) rocks enclosing cores of the Upper Carboniferous, Permian (Panjal

Volcanic series) and Triassic, closely plicated but with their roots *in situ*.

In the nappe zone to the north are more thrusts, not easily recognizable in the crystalline complex which builds the Great Himalaya range of the centre. These thrusts, however, are not of wide regional or tectonic significance. As a tectonic unit, the Great Himalaya range is made up of the roots of the Kashmir nappe, the principal geanticline within the main Himalayan geosyncline, consisting of the pre-Cambrian sedimentary rocks together with large bodies of intrusive granites and basic masses. Several periods of granitic intrusions have been observed, the latest being post-Cretaceous, or still later, and connected with the earlier phases of the Himalaya uplift. Subordinate elements of the Great Himalaya range are the southward extensions of the representatives of the Tibetan belt of marine formations belonging to the Palæozoic and Mesozoic.

In the Outer Himalaya of Mandi, S. K. Roy has noted *klippen* blocks of folded dolomite evidently belonging to the Krol series of the middle ranges, resting on the Tertiaries of the Sub-Himalayan zone. This is the only record of overthrust or *nappe* structure being observed in the mountains intervening between Kashmir and Simla [1].

(b) *The Simla Himalaya.*

Inversions in the Simla mountains

Detailed mapping and study of the metamorphic gradations in ancient rock-complexes have led G. E. Pilgrim and W. D. West (47) to conclude that the rocks of the Simla area, lying to the north of the Tertiary belt (Outer Himalayas), are not in their normal position, as previous observers had believed, but have undergone complex inversions and thrusting. Three overthrusts are noted which have trespassed over the 64 miles broad Upper Tertiary area of Kangra and constricted it to barely 16 miles at Solan. The thrusts represent flat recumbent folds of great amplitude, showing bodily displacement from the north towards the autochthonous belt of the south-west. The pre-Cambrian (Jutogh and Chail series) is piled up on the Carboniferous and Permian systems (Blaini and Krol series), the entire sequence being totally unfossiliferous. Evidence of the superposition of the highly metamorphosed pre-Cambrians (Jutogh and Chail series), building some of the conspicuous mountain tops of the area (*Klippen*) over the less altered Lower Palæozoics and Blaini beds (Upper Carboniferous), is obtained by a study of relative metamorphism and the structural relations of thrusts and uncon-

[1] *Q.J. Geol. Min. Met. Soc. Ind.* V, 131, (1933).

formities. The older rocks, now isolated, were once part of a continuous sheet over this area but are now separated from the roots in the north by the deep valley of the Sutlej. To the south of the thrust zone, in the foot-hills, the older Tertiaries (Nummulitics) are separated from the newer Tertiaries of the foot-hills by the series of parallel reversed faults which have been designated as boundary-faults.

Nappe zone of Simla region

The nappe zone of the Simla region commences some miles north of Solan and follows a meandering E.S.E. course separated from the autochthonous belt (composed of the Krol series) by the two great thrusts, Chail and Giri, which correspond approximately with the Panjal thrust of the western Himalaya. The outer limit of the Krol belt is the Krol thrust, corresponding to the Murree thrust of Kashmir. As shown by Auden, the Krol thrust itself is steeply folded by later disturbances which have plicated the Krol belt. This Krol belt (2), which tectonically corresponds with a part of the south-west flank of the Panjal range of Kashmir Himalayas, extends along the Outer Himalayas for 180 miles south-east of Solan in a tightly compressed sequence of Permo-Carboniferous strata. Near Solan, Tertiary rocks crop out as ' windows ' from under the Krols (? Permo-Carboniferous).

W. D. West is continuing the field work to the north in this area and is tracing the continuity of the nappes to the root zone in the crystalline area beyond the bend of the Sutlej. He has mapped in the Shali-Sutlej area a ' window ' exposing younger rocks by the denudation of the overlying older rocks. The sides of the window are formed of the Chail series showing an *epi* grade of metamorphism. Within the window there occur Upper Palæozoic, Nummulitic and Miocene rocks, dipping quaquaversally beneath the Chail cover. The base of the Chails is a plane of mechanical contact and marked discordance, some recumbent folds and thrusts being developed in the Tertiary and Palæozoic strata immediately beneath the Chail thrust.

(c) *The Garhwal Himalaya.*

The tectonics of this part of the Himalaya are discussed in a recent paper by J. B. Auden. Two nappes, the Krol and the Garhwal nappe, are superposed on one another and thrust forward to the obliteration of the autochthone at places. Middlemiss and Griesbach's previous study of this section of the Himalaya had given, in conformity with the tectonic ideas prevalent then, a simple interpretation to the profile across the Garhwal Himalaya, involving no horizontal displacements.

Proceeding north-east from the Sub-Himalayan Upper Tertiary zone (Siwalik and Dagshai), there are encountered, according to Auden, the following well-defined units :—

Tectonic elements of the Garhwal mountains

(1) The autochthonous fold-belt composed of a substratum of Simla slates folded in with the Eocene, Dagshai and Siwalik series. Its outer boundary is the reversed fault, the 'main boundary fault' of Middlemiss.

(2) The Krol nappe, composed of a thick succession of rocks of the Krol series (probable Permo-Carboniferous) overthrust upon the Nummulitics and Dagshais of (1). The maximum thickness of the succession in the Krol nappe is of the order of 20,000 feet. This sequence is a normal one and there is no inversion due to recumbent folding (2).

(3) The Garhwal nappe, superposed on the Krol nappe, the relations being such that the Nummulitic, Jurassic and Krol rocks belonging to the underlying Krol nappe, completely surround the older Palæozoic metamorphosed and schistose series of rocks of the superincumbent nappe and dip below them in a centripetal manner.

(4) The Great Himalaya range of crystalline phyllites and schists, made up of metamorphosed elements of the Garhwal nappe (which had its root in this part), together with the phyllites, para-gneisses and schists, and intrusive granite bodies. It marks roughly the apex of the geanticline within the main geosyncline of the Himalaya.

(5) The Tibetan zone of fossiliferous sediments, ranging in age from Cambrian upwards to the Cretaceous, is confined to the north of the last zone in this part of the chain, unlike Kashmir, where it occurs considerably to the south of the crystalline axis. The high peaks of the snowy central range of the Himalaya, generally composed of granitic rocks define the southern limit of this zone.

(d) *The Eastern Himalaya—Mount Everest Region.*

The successive Mt. Everest expeditions have brought forward data from which it is possible to interpret the tectonics of this region. The stratigraphical work of A. M. Heron and later of L. R. Wager enable us to do this (23). Both the Tertiary (Siwalik-Nummulitic) zone of the foot-hills and the autochthonous belt are greatly narrowed in this part, though the tectonic relations indicate the same large-scale inversions. The Siwaliks are in mechanical contact with the terrestrial and fluviatile Permian beds (Gondwana), which again are overthrust northwards by the pre-Cambrian Daling series of Darjeeling. This thrust bounds the nappe zone of this area, which has here transgressed considerably further southward over the autochthonous than in the areas we have considered.

Geology of Mt. Everest

Mt. Everest and its satellite peaks lie on a culmination of the Great Himalaya range, marking approximately the southern limit of the Tibetan sedimentary zone. Altered and crushed rocks belonging to

the latter, rest over the foliated gneissic complex of Everest with a prevalent northerly dip, commencing with metamorphosed Permian series of shales, limestones and quartzites, containing a brachiopod fauna with some deformed *Productus* and *Spirifer*. The actual summit of Mt. Everest (29,002 ft.) is composed of a limestone coming below this Permian series. From this bottom bed there is an ascending series of strata towards the north encompassing the Triassic and Jurassic systems, indicating a decreasing degree of mechanical deformation. In the longitudinal synclinal folds into which these are plicated, Cretaceous and Eocene strata are recognized by their fossils. A broad belt of these Mesozoic and Eocene rocks was traversed by Sir H. H. Hayden and Sir Sven Hedin during their travels in southern Tibet.

The Eocene is the newest stratigraphical system detected in the Tibetan zone of the Himalaya from Kashmir to Sikkim. Eocene strata are involved in the earliest system of flexures of the central ranges at both these localities.

From the data available we recognize in the chief structure-zones of the Sikkim Himalaya, eastward prolongations of the tectonic zones of Garhwal, Simla and Kashmir, though in greatly varying widths.

(e) *The Trend-line of the Himalaya—its N.-W. and S.-E. limits—The Himalayan Syntaxes.*

The Hazara-Kashmir Syntaxis

The trend-line of the Himalaya forms an interesting study of the mechanics of mountain-building and of the reactions of the old stable blocks of the earth's crust against the weaker zones of the earth, the geosynclines. Recent work tends to establish the fact that the trend of the Himalaya is determined by the shape of the Archæan massif of Gondwanaland which is believed to have played a passive rôle against the southward advance of the waves of crustal folding which elevated the Tethyan geosyncline. For 1,500 miles, from Assam to Kashmir, the Himalayan ranges follow one dominant orogenic strike, at first E.-W., later S.E.-N.W. and then appear to terminate suddenly at the peak of Nanga Parbat (26,620 ft.), one of the greatest eminences on the central axis. This abrupt termination was a puzzle; topographic surveys failed to find any line of heights to continue the chain west of the Indus. Geological survey of the country (44), however, clearly showed a sharp southward bend of the mountain-strike on itself, pursuing at first a south and then a south-west course, through Chilas and North Hazara, instead of pursuing a N.-W. course through Chitral.

Wadia in 1931 suggested that the acute bend is due to the moulding of the Himalayan orogene as it emerged from the Tethys round a tongue-like projection of Gondwanaland—the Punjab wedge. On meeting with this obstruction, the northerly earth-

pressures resolved into two components, one acting from north-east, the other from north-west, against the shoulders of this triangular promontory. Thus it has happened that the Hazara mountains are, in their geological structure and composition, a replica of the Kashmir mountains. Westward the axial continuation of the Himalayan geosyncline is observable as far as Campbellpur, beyond which it will be decided by future field work on the Irano-Afghan frontier.

The Assam Syntaxial angle

The eastern limit of the Himalaya beyond Assam is as yet largely a matter of conjecture. This part of the Himalaya, geologically speaking, is still a *terra incognita* as far as its stratigraphy and rocks are concerned. The tectonics of the interior parts are likewise unknown. Nevertheless the few data that are available from field observations in the Dafla, Abor and Mishmi hills, Sadiya, Hukawng and Patkai ranges permit some tentative views on the strike and alignment of the ranges. The structural strike of the mountains and the disposition of the fold-axes at the above-named localities strongly suggest a deep knee-bend of the Assam Himalaya towards the south, the re-entrant being, in this instance, deeper and more acute than is the case with the north-west syntaxis. The obstructing block in the present case must be the *massif* of the Assam plateau, connected underground through the Rajmahal hills with the Peninsular *horst*.

Tectonics of the Assam mountains

The south flank of the Assam Himalaya shows a general north or north-west dip of the beds, the faults and thrust-planes also heading in the same direction. On the opposite flank of the deep hairpin bend, enclosing the valley of Assam, are the Naga hills, showing south-easterly dips along with a number of strike-faults and thrust-planes, all heading towards the same direction. P. Evans[1] considers that there is much evident similarity between the disposition of the Tertiary strata of the Himalaya and those of the Naga hills, and the age of faulting also, as far as can be ascertained, is the same. The compression of the tongue of foreland enclosed and overthrust by the two flanks of the syntaxis is enormous, as if between the two jaws of a vice. According to C. S. Fox and P. Evans (13), who have carried out detailed field work in the Assam hills and the plateau country, the Assam valley is a good example of a 'ramp valley' that has by pressure and overfolding been so jammed that its present breadth is only a small fraction of the original. During this process the central *massif* of the Shillong plateau was sliced by cross-faults into blocks that have been pushed southward *en echelon*.

Palæontological evidence supports the inference that the Himalayan chain bends southwards and does not continue on its

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[1] In an unpublished communication.

eastward alignment into China. The Mesozoic flora of Burma is different from the homotaxial Upper Gondwana flora of India and is more allied to the flora of China—a quite distinct palæo-botanical province from India. This separation of the life-provinces of Gondwanaland and China, lasting from the Upper Carboniferous to the Cretaceous, is a fact well established by Halle and Sahni; the cause of this separation can only be attributed to the interposition of the barrier of the Tethys sea. Again, the Cretaceous system of Burma reveals no connection, faunistic or stratigraphic, with contemporary deposits of the closely adjacent Assam province (a part of Gondwanaland), but it shows marked affinities with the Cretaceous of Sind and Baluchistan—a Tethyan province. The Tibetan zone of Himalayan stratigraphy, disposed to the north of the crystalline axis of this mountain chain, extends into Sind on the west side and to Burma on the east.

(*f*) *The Arcuate Form of the Himalayas and their Relation to the Central Asiatic Mountain-systems.*

Recent work in Ferghana by Mushketov, in the Pamir region by Russian geologists, and in the Himalaya by the Geological Survey of India tends to establish a unity of structural plan and features, disclosing a common cause and origin for all the great mountain-systems of Central Asia, both of the Hercymian and of the Alpine age (31, 42). It is, however, probable, as Argand believes, that the powerful crust movements of the Tertiary and post-Tertiary Alpine orogeny superseded, and in a great measure altered, the old Altaid trend-lines of Asia; the existing alignment of all the ranges, therefore, which meet in the Pamir knot, is largely the work of the late Tertiary diastrophism. The orientation of the Tien Shan-Alai-Kuen Lun system of radiating chains of the north, that of the Hindu Kush-Karakoram arc of the middle, and of the deeply reflexed Himalayan arc of the south, all fuse in the Pamir vertex or knot, a crust segment possessing unique significance as having an equatorial strike orientation in the midst of numerous divergent trend-lines radiating away from it. To the south of the Pamir is the Punjab wedge, the pivot on which are moulded the Himalayan syntaxis and the Hindu Kush-Karakoram syntaxis. This N.-S. line of the crust connecting the Pamir with the Punjab is thus of critical importance in the orography of Asia and will take a key position in future work on orogenesis and mechanics of crustal motion in mountain-building.

The Pamir Knot

The festooning of the Himalayan arc, caused by the reaction of the more plastic earth-folds pressing against the Indian *horst* is of great interest. We have seen the two most prominent of these in the Punjab and Assam wedges causing acute looping of the mountain-arcs. An equally abrupt syntaxis of the mountain-folds, which

The rôle of the Indian horst

belong to the south-east flank of the Suleiman bifurcation of the main Himalayan axis as it joins on with the Iranian arc to the west, is seen near Quetta in Baluchistan. This comparatively minor but most spectacular re-entrant shows a bundling up of a multitude of normal anticlines and synclines of Tertiary, Cretaceous and Jurassic strata into a closely packed sheaf and forced out of straightness by two abrupt curves involving a bending of the axes under the northerly pressures through angles of 120° and 150°. It is significant that this re-entrant is an area of marked seismic activity (48). W. D. West, who investigated the Quetta earthquake of 1935, regards its origin as largely due to the strain of the tight packing of folds in the Quetta syntaxis.

From these considerations the view is expressed that the Great Himalaya Range, from the gorge of the Brahmaputra in the east to Nanga Parbat on the Indus in the north-west, denotes the Himalayan protaxis, the axis of original upwarp of the bottom of the Tethys geosyncline. At both its ends it has undergone sharp southward deflections owing to the termination of the obstruction offered by the north edge of the Gondwana-block and its projecting angles and capes.

(g) *The Age of the Tectonics of North India.*

Evidence of the extreme youth of Himalayan orogeny has multiplied of recent years. The tilting and elevation of the Pleistocene lake and river deposits of the Kashmir valley (Karewa series) containing fossil plants and vertebrates, to a height of 5,000–6,000 feet; the dissection of river-terraces containing post-Tertiary mammalia to a depth of over 3,000 feet and overthrusting of the older Himalayan rocks upon Pleistocene gravel and alluvia of the plains have been noted by the Geological Survey of India and other observers (De Terra). The initiation of Himalayan mountain-building took place in (1) post-Nummulitic, Oligocene, time at the earliest, since which the two major phases of upheavals, as revealed by clear stratigraphic evidence, are (2) the post-Miocene, during which the Simla *nappes*, the Krol and Garhwal *nappes* and the Kashmir *nappe* were formed, and the broad piedmont zone of Murree sediments was plicated, and (3) the post-Pliocene, continuing late into the Pleistocene, which has uplifted the Upper Siwalik sediments to a steeply inclined or vertical position in the Punjab foot-hills. The great downwarp of the Plains of Punjab, Bihar and Bengal was concomitant with (2) and (3) phases of Himalayan elevation.

Three phases of uplift of the Himalayas

In the Salt Range and in the Assam ranges, two periods of uplift are recognized: (1) post-Eocene or Oligocene, and (2) Pliocene, which continued till late into the Pleistocene. This latter diastrophism was probably a sympathetic event accompany-

ing the final Himalayan phase. The Assam plateau has received also an epeirogenic uplift during the late Tertiary.

No Mesozoic or late Palæozoic tectonic movement of orogenic description is detected in the Indian foreland, though minor warps, e.g., minor marine transgressions during the Uralian, Jurassic and Cretaceous, which penetrated the heart of the Peninsula, accompanied by block-dislocations, have occurred time and again during the long geological interval. The latest orogeny of the Peninsula is assigned to the post-Vindhyan and pre-Talchir (Uralian) interval, which folded the peneplaned Aravalli synclinorium into a rejuvenated chain, involving in its plication a selvage of horizontally bedded Vindhyans (? Cambrian) on its east flank.

No post-Vindhyan orogeny in the Deccan

There was no well-defined Caledonian cycle of earth-deformation in India, while the Hercynian revolutions manifested themselves in initiating the Tethys, in bringing about wide changes in land and water distribution, and in tensional faults in the Peninsula, but not in the creation of folded mountains.

VIII. The Indo-Gangetic Trough.

(a) *The Main Trough.*

The great plains of Northern India, the hitherto neglected chapter of the geological history of India, have received much attention since 1916 from geologists [R. D. Oldham (32), Sir H. H. Hayden (21) and others] mainly on account of the interest of the geodetic and geophysical investigations revealing something of the structure, contour, and composition of their floor. All geologists now recognize that this great alluvial plain covers a trough which is of the nature of a 'foredeep' produced by a sagging of the foreland, in face of the advancing Himalayan folds. This was Suess' conception. R. D. Oldham concluded from a survey of geological and geodetic evidence that the maximum depth of the trough was 15,000 ft. near its northern limit, from which the floor sloped upwards to its southern edge, where it merges with the edge of the Vindhyan uplands north of the Deccan (32, 21).

A structural basin

More recent revised calculations by Lt.-Col. E. A. Glennie of the Geodetic Survey have made considerable additions to our knowledge of the depth, shape and topography of the bottom of the trough. Glennie allows only 6,500 ft. as maximum thickness of the lighter alluvial deposit resting on the denser Archæan bed-rock. While this figure is too low for geological requirements and cannot satisfactorily account for the Murree and Siwalik deposits,

some thickness of which must underlie the more recent alluvium, it helps to check any exaggerated conception of the thickness of the alluvium (10).

Corrugations of the floor

How far southward the Murree and Siwalik deposits of the foothill zone extend underneath the Indo-Gangetic alluvium we have no means of determining, except possibly by gravity and magnetic surveys. A submerged ridge in structural prolongation of the Aravalli axis at Delhi and striking north-eastwards towards Hardwar is revealed by gravity survey. Another underground ridge of dense rock is marked out by torsion balance and pendulum observations between Delhi and the Salt Range, connecting the isolated hillocks of Sargodha. Here the alluvium must be shallow. The depth of the alluvium is at its maximum between Delhi and the Rajmahal hills and shallow in Rajputana and between the Rajmahal hills and Assam.

The downwarp which produced the Gangetic geosyncline (in this case the subsidence was not deep enough to carry its surface beneath the sea-level, except temporarily at the beginning) must have started as a concomitant of Himalayan elevation to the north, somewhere in the mid-Eocene. The deposition of the debris of the newly rising mountains and sinking of the trough must have proceeded *pari passu* all through the Tertiary up to within late Pleistocene and sub-Recent times.

Folding and faulting at the north margin

There is evidence of a considerable amount of flexure and dislocation at the northern margin of the trough, passing into the zone of the various boundary faults at the foot of the Himalaya; it is possible that a certain amount of folding and faulting extends southwards to the bottom of the downwarp. At any rate, it is clear that the northern rim of the great trough is under considerable tectonic strain due to the progressive down-warping, with the greatest subsidence where it merges into the foot of the mountains. The seismic instability of this part of India is well known, it being the belt encompassing the epicentres of the majority of the known earthquakes of Northern India. Field investigations on the recent Bihar earthquake of January, 1934 point to some crustal disturbance below the Gangetic valley between Motihari and Purnea as the cause of the disaster. A memoir, by D. N. Wadia, J. A. Dunn, J. B. Auden and A. M. N. Ghosh, on the geological aspects of this earthquake is under publication.

The southern limit of the trough shows no structural peculiarities or features of any importance.

(b) *The Potwar Geosyncline.*

This basin is a north-westerly branch of the main Indo-Gangetic depression. D. N. Wadia has drawn attention to the intimate struc-

tural connection between the Potwar geosyncline of the north-west Punjab—a basin encompassing 25,000 ft. of Tertiary sediments in one conformable sequence—and the main Indo-Gangetic depression (43). The rock-sequence in the Potwar basin-fold epitomises the Tertiary geology of Northern India. This syncline is 70 miles broad and 150 miles in length along its strike, tapering out east of the Jhelum into the Siwalik foot-hills zone. The Potwar basin is the smaller north-westerly ramification of the Indo-Gangetic trough, the other southward and larger branch being the Rajputana trough.

The southern edge of the Potwar basin is the great scarp of the Salt Range mountains, a disrupted monocline; while its northern rim is the isoclinally folded Kala Chitta range at the south border of Hazara.

To the south-east the Potwar basin-fold gradually flattens and widens into the broad Indo-Gangetic trough.

IX. Recent Advances in Palæontology in India.

Four main lines of advance

Notable contributions to our knowledge of palæontology in India during the last twenty years have been along four main lines: (1) the investigation of the invertebrate Palæozoic faunas from the ancient life-provinces of the Salt Range, Kashmir, the Chitral and Pamir region, and the Shan States of Burma; (2) the study of the rich mammalian faunas entombed in the Siwalik and older Tertiary fresh-water deposits of the Himalayan foot-hills and those of the Baluchistan and Burma highlands; (3) the detailed examination of groups of marine Mesozoic and Eocene fossils, e.g., the Jurassic cephalopods of Cutch, the Danian faunas of the *Cardita beaumonti* horizon, the basal Eocene mollusca of the Ranikot series and the Eocene foraminifera from the calcareous mountains of the north-west; and (4) the revision of the fossil floras of the Gondwana system in accordance with the advances in palæobotany that have been made since Feistmantel carried out his pioneer investigations on the terrestrial fossil vegetation of India between the years 1863–86.

Invertebrate palæontology

A number of important monographs on the fauna of the older Palæozoic and the 'Anthracolithic' formations of the Himalaya, Burma and the Salt Range by Dr. F. R. Cowper Reed (39), have brought the problem of the geographical distribution of the life-provinces in the Palæozoic seas of India nearer satisfactory solution. According to Dr. Reed, the Himalayan Palæozoic faunas are notable for their closer relationship to American fauna than to those of Eurasia. The Devonian and Carboniferous of Chitral and Afghanistan, on the

other hand, have a decided relationship with Europe; so also the rich Palæozoic faunas of the Shan States of Burma are European in character and have little affinities with the Himalayan Palæozoics. In the field of invertebrate palæontology in India, Dr. Reed is the successor to the late Prof. Carl Diener of Vienna, who for many years before the War was a most valued collaborator with the Geological Survey of India in working out its collections of the faunal wealth of the Spiti, Kumaon and Kashmir Himalayas. As a consequence of detailed palæontological study, following closely on systematic mapping and collecting in the field by officers of the Geological Survey, the age of Permo-Carboniferous glaciation of India, a most important datum-line in the geology of the whole of the ancient southern continent of Gondwanaland, is now deduced with considerable precision to belong to a horizon at the base of the Uralian or the top of the Moscovian stage—a horizon which is now accepted by Indian geologists as forming the bottom of the lower Gondwana system of deposits in all parts of India.

Mammalian palæontology

Dr. G. E. Pilgrim has been the chief investigator of the Tertiary mammals of India during the last two decades (35). His notable contributions are memoirs on the Eocene ungulates from Burma, the Lower Miocene anthracotheroids from the Bugti Hills of Baluchistan, the fossil pigs, giraffes and carnivores of India, together with a forthcoming comprehensive review of the hollow-horned ruminants which are so prolific in the Siwaliks. In very suggestive papers Pilgrim has discussed the problem of the phylogeny, inter-relations and migrations of the various groups of pre-historic mammals into and out of India during the Siwalik epoch, when India's population of the higher mammals was far greater than it is to-day. An important element in the mammalian fauna of the Siwaliks consists of the remains of creatures belonging to the most highly developed order of the primates, these including some fifteen genera of anthropoid apes, extending in stratigraphic range from middle Miocene to early Pleistocene. The fossil primates so far discovered are, however, unfortunately very fragmentary and in the present stage of our knowledge no definite conclusions as to the probable lines of descent of these forms and their position with respect to the line of human ancestry in India can be safely drawn, yet the proof of the presence of a vigorous and highly differentiated family of the anthropoid apes (Simiidæ) in an epoch directly anterior to that of man, suggests that the idea of the existence of Upper Siwalik Man in India (the yet undiscovered *Sivanthropus*) may not be merely a dream.

Cretaceous Dinosaurs

Since 1920 our knowledge of the Mesozoic reptiles of India, especially of the extraordinarily diversified order Dinosauria, has been greatly increased by the finding of large quantities of vertebræ, skull, limb and girdle bones, armour-plates, and teeth, from the

Jubbulpore district, by Dr. C. A. Matley, working in co-operation with the Geological Survey. The systematic description of this material by Prof. Von Heune of Stuttgart, a recognized authority on fossil reptiles, and Dr. Matley, has added 12 new genera and many species to the list of Indian dinosaurs, including the first records of the sub-orders Cœlurosauria and Stegosauria in this country (28). The chief genera are *Titanosaurus*, *Antarctosaurus*, *Indosuchus*, *Lametosaurus*, *Laplatasaurus*, *Jubbulporia*. The dinosaurs reached their highest development in India during the Lameta age in the Upper Cretaceous period. Von Heune states that the Central Provinces fossil dinosaurs are closely allied to those occurring in the Cretaceous of Madagascar and also with those found in Patagonia and Brazil. This would suggest land-bridges in the existing Indian and Atlantic oceans, or the persistence of remnants of the old Gondwana continent.

Jurassic Cephalopods

Dr. L. F. Spath of the British Museum has completed his revision of the Jurassic Cephalopoda of Cutch, comprising 556 species of ammonites divided into 114 genera, the majority of these being the author's own creation; the fauna is described in six bulky memoirs of the *Palæontologia Indica* (41). Dr. Spath has discussed interesting questions of Jurassic zoo-geographical provinces, the affinities and comparisons of contemporaneous faunas from other parts of the world and the fascinating problem of ammonite phylogeny, in the investigation of which he finds the Haeckelian theory of Recapitulation, or as it is termed, 'Biogenetic law', quite inadequate. The main elements of the Cutch fauna, according to Spath, are more closely linked to the fauna of the Indo-Madagascar province than to the Mediterranean (i.e., Tethyan) area.

Gondwana Floras

The pre-eminent position occupied by the Gondwana system among the stratified formations of the Peninsula has, from the earliest days of Indian geology, enforced attention to palæobotanical studies, not so much for the purpose of establishing chronologies (for which the value of the evidence of plant fossils is still not fully established) but for the classification and intercorrelation of stages of the various widely scattered Gondwana outcrops of India from Kashmir in the north-west to the mouth of the Godavary in the south-east. In 1920 Seward and Sahni published a memoir on the revision of some Gondwana plants; this paper has drawn attention to the necessity of a comprehensive re-study of the great store of plant petrifications, impressions, woods, fructifications, etc., belonging to the original material worked out by Feistmantel, as well as that collected by the Geological Survey during the last fifty years. The recognition of the Pteridosperms as a group distinct from the ferns and of the Bennettitales as distinct from the Cycads, along with the improved methods and technique of investigation of fossil plant-tissues that have come into use during recent years, have already caused con-

siderable modifications in the grouping and nomenclature of Gondwana plants. Since 1925 the work of revision has been carried out by Prof. B. Sahni of Lucknow University and two memoirs dealing with the Coniferales (40), besides several smaller papers on subjects of special interest, have already been published. Prof. Sahni is at present engaged on a comprehensive study of the post-Gondwana fossil Monocotyledons collected from various parts of India.

During the past few years, Sahni has made several contributions to Indian palæobotany. Notable amongst these are his record of the only coniferous wood so far known from the Shan States, the first discovery in India of the genera *Matonidium* and *Weichselia* which are characteristic of the Jurassic and Wealden strata of Europe, and a number of papers dealing with the age of the Deccan traps, now accepted as Tertiary. In another paper, Sahni refers the Parsora beds to the Permo-Trias, instead of to the Upper Gondwana (Jurassic) to which these were assigned by Dr. C. S. Fox on stratigraphical grounds. His discovery of an angispermous wood in the Rajmahal beds raises interesting speculations as to its affinities and the age of the beds in which it occurs (p. 94).

Prof. Gothan expresses the opinion that the few fossil plants entombed in the Po series of Spiti are of lower Carboniferous age and in this respect follows the view held by Zeiller.

Palæontological work of recent years

Among other noteworthy palæontological work of recent years may be mentioned the establishment of a remarkably well developed Cambrian system in Kashmir, containing a highly differentiated, but strongly provincial, fauna of trilobites, and of the Neocomian and Albian horizons in the Cretaceous of the Kohat area. The value of Foraminifera as zone fossils in stratigraphic correlations of stages and sub-stages of the extensive Eocene and Oligocene calcareous development of the north-west, is brought out by the work of W. L. F. Nuttall and L. M. Davies.

In a recent contribution D. N. Wadia has proved the occurrence of Cretaceous rocks in the Kashmir Himalayas and records the presence of the characteristic Cretaceous foraminifer *Orbitolina* in these beds. The discovery that the *Orbitolina*-limestone was intruded by the hornblende-granite of Astor, stamps the age of this large body of granite as post-Cretaceous. This is the only definite evidence of the age of a Himalayan granite which has become available in recent years.

Palæontological publications which have appeared since 1933 are :—

Recent noteworthy publications

Dr. F. R. Cowper Reed has made known the faunas of the Shan States of Burma and the Salt Range in a number of memoirs. Dr. L. F. Spath has published a number of valuable memoirs dealing with the Cephalopod faunas of India.

Prof. Julius Pia of Vienna and L. Rama Rao (38) have given a detailed description of Fossil Algæ from the Niniyur group of South India. Certain specimens from the Vindhyan rocks of India which have been referred variously to the plant and animal kingdoms, and have even been regarded as inorganic, were described in 1935 by Dr. Frederick Chapman of Melbourne, Australia, as Atrematous and Neotrematous Brachiopoda. He assigned three species to his genus *Fermoria* and one to *Protobolella*. M. R. Sahni, who re-examined the type and other material in detail, has thrown considerable doubt upon this classification and considers the brachiopod affinities of these fossils as very doubtful. He prefers to assign them to a separate family, the Fermoridæ, and recognizes only one instead of three species of *Fermoria*, the others falling into synonymy with it. More material needs to be examined before the true affinities of these fossils can be ascertained.

In a short note M. R. Sahni records the occurrence on the foreshore at Puri, of a lamellibranch species closely allied to *Paphia gregaria* (Partsche), a Miocene form. The specimens were not found *in situ*, but their embedding matrix is identical to that obtained from a boring at Baripada, Mayurbhanj State, more than a hundred miles to the north-east of Puri, containing *Amphistegina* and *Ostrea* of probable Miocene age. It appears probable that Tertiary rocks extend from Baripada and occur underground near Puri.

Of recent fossil discoveries in Burma may be mentioned Lr. Triassic ammonites from the Northern Shan States and a well-preserved Devonian fauna from Me-so in the Southern Shan States, both by M. R. Sahni. V. P. Sondhi in 1930 discovered a large and important graptolitic fauna from the Southern Shan States, identified as belonging to the Valentian and Salopian horizons of the Silurian. E. L. G. Clegg discovered Cretaceous beds in the Second Defile of the Irrawaddy in 1936.

Mollusca from the freshwater Inter-trappean beds and from the Upper Tertiaries have received scanty notice. Among important contributions describing these are a number of papers on *Lamellidens*, *Indonaia*, and *Potomida*, of comparatively recent aspect, by B. Prashad and E. Vredenburg. A review of fossil Unionids of the Siwalik series has lately been published by H. E. Vokes in a memoir of the Connecticut Academy.

A magnificent collection of animal and plant fossils, the result of nearly seven decades' collecting by the Geological Survey, is stored in the galleries of the Indian Museum at Calcutta. Free access to these collections is given to students and specialists and the Museum is actively furthering palæontological research by its system of exchange and presentation of duplicate specimens, casts, etc., to museums in many parts of the world. Between 1932 and 1936 on several occasions, the Indian Geological Survey co-operated with the Yale University expeditions under Dr. de Terra in making large collections of invertebrate and vertebrate fossils from the

Permo-Carboniferous of the Salt Range and the Siwalik deposits of the Potwar. Simla and Kangra areas, and with the British Museum Percy Sladen Trust party in collecting fossil reptilian remains from the Central Provinces.

A welcome sign of the times is the interest taken in palæontological work by some of the younger workers in Indian geology. Considering the serious and often unsurmountable limits to palæontological research by those beyond reach of organized departmental centres, e.g., properly equipped libraries and museums, the progress, though slow, gives cause for satisfaction. Besides some excellent palæobotanical works produced by Prof. Sahni's research students, the Geology Department of Bangalore and Benares are making creditable endeavours to encourage palæontological research on the right lines.

X. Economic Geology.

Development of minerals

During the period under review there has been a remarkable progress in the economic geology of India. The Geological Survey of India have for many years published quinquennial and annual reviews of the mineral production, and a comparison of the most recent review with that of 25 years previously shows the degree of advance that has been made in the development of the country's mineral resources. During this period the value of the minerals produced has doubled, and there have been extensive enquiries into the distribution and mode of occurrence of the more important deposits. The economic side of the work of the Geological Survey of India is even more extensive than might be gathered from a perusal of the varied list of memoirs on economic subjects ; the annual general reports of the Survey's activities show the increasing attention paid to applied geology, especially in such matters as dam sites, railway alignments, borings and underground water supplies, and besides this, enquiries are constantly being received from industrial concerns.

Descriptive memoirs

The more important publications on mineral resources include Dr. Fermor's report on manganese (which appeared just before the period with which we are concerned), several volumes on the coal-fields by Dr. C. S. Fox and others, a number of papers on the iron ores, and others dealing with wolfram, bauxite, the refractory minerals, barytes, asbestos, etc., to some of which reference has already been made.

Petroleum

An instance of the happy combination of 'pure' and 'applied' geology is the series of papers by Sir Edwin Pascoe on the petroleum occurrences of India and Burma. In these he has summarized the stratigraphy and struc-

ture of the Tertiary rocks of a large part of India and Burma, adding many geological maps of the oil-producing areas, besides giving an account of the oil industry and discussing the prospects of further developments. His work has been followed up by accounts by C. T. Barber of modern oilfield practice, and of the natural gas resources. Besides the publications of the Geological Survey on petroleum geology, there have been a number of contributions by the geological staffs of the oil companies, these papers appearing in a variety of geological and technical journals. One of the most interesting developments of the geological work of the oil companies is the extensive application of sedimentary petrology to correlation problems referred to above. It might be said that the period under review has seen almost the entire growth of the science of oil geology, and a perusal of the literature will show that, in proportion to the oil production of the country, India has taken its fair share in the advancement of the growing science.

Coal

In the course of their work on the coalfields, the Geological Survey have produced large scale maps of all the important Gondwana coalfields to accompany the descriptive memoirs; in addition, complete maps of the Jharia and Raniganj coalfields on the 4″ scale have been prepared for sale to the public. Many papers discussing geological problems associated with the coalfields have appeared in the journals of the scientific societies, particularly in the Transactions of the Mining and Geological Institute of India and more recently in the Quarterly Journal of the Geological, Mining and Metallurgical Society of India.

Ores

The Archæans (and to a smaller extent the other pre-Cambrian rocks) have been the subject of an important literature dealing with their economic aspects; the manganese ores have been discussed especially by L. L. Fermor, and the iron ores by C. Jones, F. G. Percival, E. Spencer, and several officers of the Geological Survey. J. A. Dunn has recently described the ores of Singhbhum, A. L. Coulson the barytes and asbestos of Madras, and G. V. Hobson and S. K. Roy the mica deposits of Bihar. Dr. Heron has published a detailed survey of the economic rocks and minerals of Rajputana and M. S. Krishnan the mineral deposits of Gangpur. Important data concerning these mineral resources have appeared in the annual and quinquennial reviews of mineral production prepared by successive Directors of the Geological Survey.

An excellent series of monographs on economic mineral deposits of Kashmir has been published by C. S. Middlemiss (30) on coal, lignite, bauxite, copper, zinc and nickel-ores, sapphires, etc., based on accurate surveys.

XI. Geography and Geodesy.

[The Geographical and Geodetical Work of the Survey of India.]

(a) *Progress of Geography in India.*

The most important geographical work done in India during the last century and half is in connection with the topographical mapping of India for administrative, military and revenue purposes. This work commenced in the early days of the East India Company as military route surveys. The initiation of detailed topographical surveys, based on a rigid framework, seems to have been somewhere about the closing years of the eighteenth century, when the Great Trigonometrical Survey of international fame came to be instituted under William Lambton. This stupendous framework, now reaching completion, has accurately placed India on the map of the earth. The purely map-making work of the Survey of India, however, began at an earlier date—1767,—ten years after the battle of Plassey, and it has up till to-day surveyed and mapped 1,304,453 sq. miles of India and Burma out of a total of 1,884,640 sq. miles on a standard of accuracy equal to that of the surveys in Europe. As ancillary to topographical surveys and the maintenance of geographical maps of the greater part of Southern Asia, there are a number of field-operations and activities of a purely scientific nature maintained by the Department. The routine geographical work of the Survey falls into four parts—general, geodetic, topographical and map-publication. The purely scientific activities are :—

Survey commenced in 1767

(1) *The principal triangulation of India.*—The foundation and controlling framework for measuring the figure of the earth in India and for the control of horizontal topographical measurements.

(2) *Levelling operations*, controlling vertical measurements as a basis for topographical heights ; erection of standard bench-marks and preparation of level-charts.

(3) *Astronomical operations* for determination of latitude, longitude and time ;—location of India in its correct position on the globe. The origin of Indian triangulation was a point in Central India.

(4) *Pendulum operations* for observation of the direction and force of gravity in order to correct the astronomical results from the unavoidable errors caused by deflections of gravity at a particular point of observation.

(5) *Tidal operations*, to provide a datum for levelling work of the Survey, for tide predictions between Suez and Singapore and obtaining evidence for the rising and sinking of the land and of the mean sea-level.

(6) *Magnetic Survey* to determine the declination, dip and intensity of the earth's magnetic force in different parts of India. This was undertaken in 1901 and closed down in 1920. Field observations were made at 1,400 stations; 80 repeat stations were observed at 5-year intervals.

Scope of work

The astronomical, trigonometrical and geodetic results accomplished during the pursuit of the above-named activities of the Department since its inception constitute one of the finest records of scientific work achieved in any part of the world. The high objective of the workers in this branch and their endeavour to maintain an unremitting liaison with advanced science is seen in the following quotations from a paper by Sir Sidney Burrard, late Surveyor-General of India, then Col. Burrard, F.R.S., Superintendent of the Trigonometrical Surveys, reviewing past work of the department, in 1905 (Prof. Paper No. 9, Calcutta, 1905):—

'The primary object of a national survey is the making of maps, and all operations are subordinated to that end. It is for topographical purposes that a national survey measures its allotted span of the earth's surface. If, however, these measurements be subsequently combined with astronomical determinations, the size and shape of the earth can be deduced, and a knowledge of this size and shape is essential to astronomers, geographers, geologists and meteorologists, all of whom look to Surveys for information' ..... 'The great accuracy of modern astronomical observations for stellar and lunar parallax are constantly necessitating more refined determinations of the figure of the earth, and astronomy is continually bringing pressure to bear upon Surveys to lend her their aid—for her celestial measurements must always emanate from a terrestrial base' ..... 'The determination of the figure of the earth and of the dimensions and of the specific gravity of the geoid is now in the hands of an International Geodetic Association. India's co-operation is the more valued by the Association, because she alone of the civilised nations possesses an equatorial area, and because she includes within her dominions the highest points of the earth's surface.'

'The area of India is more than one-fourth of the total triangulated area of the world: it is the largest triangulated area that has yet been undertaken by one Survey; it is the largest triangulated area that has ever been made to emanate from a single point; and our astronomical officers have had to fit this area into its true position on the globe. They have had to discover the relative dimensions of the area to be located and of the globe receiving it: they have had to keep a watch on the triangulation, to see that it is not trespassing beyond our correct frontiers and coasts, and to warn us of the errors that we shall have to deal with when we meet with a foreign survey.'

The first authoritative map of India was published by D'Anville in 1752, when the exploration of the then unknown India was still largely in French hands. The earlier maps of the Survey of India were military reconnaissances and later chained surveys based on astronomically fixed points, and do not pretend to the accuracy of the modern maps of India based on the rigid system of triangulation commenced at Madras in 1802 and since extended over and beyond India. By 1912 India had been fairly well covered by series of

primary and secondary triangulation, but extensions are still occasionally being made.

Topographic map-sheets

Several hundred thousand topographical map-sheets of contoured survey within the borders of India and Burma have been produced within recent years on scales between $\frac{1}{8}$ inch and 1 inch to a mile, and on scales of 16 and 32 miles to an inch for public use. The total map-sheets of different districts of India now in stock and available for issue to the public number $2\frac{1}{2}$ millions. The average number of maps issued during a year is about 700, while the extent of country originally surveyed during an official year is roughly 53,000 sq. miles. Besides accurate delineation of geographical facts, these maps represent a very high standard of draftsmanship and artistic power. Besides purely topographical and geographical surveys, the Department undertakes local, forest and cantonment surveys, riverain, irrigation, railway and city surveys, estates and mining surveys, etc. The annual programme of the Survey includes, besides the publication of maps, miscellaneous computations, air-survey research, observatory work (astronomical, magnetic, etc.), the measurement of geodetic bases, principal triangulation, geodetic levelling, precise latitudes, longitudes, azimuths, gravity determinations in all parts of India, and prediction of tides at 41 eastern ports between Suez and Singapore.

Survey and exploration of the Himalayas

A fascinating chapter in the history of the Survey is the exploration by a succession of distinguished geographers and surveyors of wide tracts of Tibet and the Himalaya, though large gaps still remain in our knowledge of the geography of the central and eastern Himalayas. The orographic alignment and relations of the multitudes of ranges, peaks, passes, trade-routes, valleys, river systems, glaciers and lakes of the Western Himalaya, and of parts of Kumaon, Garhwal and Sikkim are now accurately known. In this there has been a happy and fruitful co-operation extending over nearly a century, between travellers, explorers and naturalists on the one side and the professional geographers of the Survey of India on the other. A large accession to our geographical knowledge of the least-known tracts of High Asia has resulted through the explorations of Sven Hedin in Western and Southern Tibet, Trans-Himalaya and Karakoram. Other examples are too numerous to quote here.

Air-Survey

To meet the rapidly increasing complexity of modern military requirements, an Air Survey branch, opened by the Department in 1923, carries out research on the latest methods of aerial mapping and photography. The methods utilized are those designed to produce topographical maps from both vertical and oblique air photographs. An Air Survey party has been employed on topographical air surveys principally on the North-West Frontier Province. Photographs of

areas covering about 8,000 square miles of the Frontier are stored in the Air Survey library. These maps are a potential source of much geological information as yet untapped.

About 12,000 sq. miles have been photographed from the air on topographical scales for survey purposes in various parts of India.

(b) Progress of Geodesy in India.

Geodesy serves two purposes :—

(1) It provides a framework for the topographical surveys.
(2) It provides data for the study of geophysics.

Geodesy—the measurement of the figure of the earth, including various geophysical problems—is the science of surveying large tracts of the earth. Without accurate knowledge of the shape, or as it is generally termed, the figure, of the earth (the *geoid*), the mapping of any considerable tract of the earth's surface is impossible, for the positions of determined points on that surface cannot be defined by their latitude and longitude.

Geodetic studies in India

India is particularly favourably circumstanced for the study of geodesy. In the first place its triangular shape provides from the foot of the Himalaya to Cape Comorin over 1,700 miles stretch of land over one meridian. Again, the deformation of the geoid in India is such that in no other part of the world has the direction of gravity been found to undergo such abnormal variations as have been discovered by the Survey of India in Northern India, and by the Russian surveyors in Ferghana, north of the Pamirs. According to Burrard, in no other country in the world does a surface of liquid at rest deviate so much from the horizontal. It was in India that it was discovered that a deficiency of matter underlies a vast pile of superficial matter, the Himalaya, that a chain of dense matter runs hidden underneath the Gangetic plains, that seaward deflections of the pendulum, rather than towards the Ghats, prevail round the coasts of the Deccan. These discoveries led to the formation of the theory of mountain-compensation in about 1854 by the Rev. J. H. Pratt, an Archdeacon of Calcutta, a great mathematician, a theory which was subsequently elaborated and expanded into the doctrine of isostasy. This simple and captivating hypothesis, which has had a great vogue, particularly in America, implies a certain amount of hydrostatic balance between the different segments of the earth's crust and an adjustment between the surface topographic relief, and the arrangement of density in the interior of the earth, so that if an extra load is imposed on any portion of the surface it must sink under it, while the adjacent unloaded parts must rise until equilibrium is established. The theory of isostasy had its birth in India, and although observations

The theory of Isostasy

of gravity and the deviation of the vertical confirm in some measure the theory of isostasy in its widest sense, yet as we shall see presently, it is receiving its most serious setback from the later more precise gravimetric work of the Geodetic branch of the Survey of India. For it is found inadequate to explain the large anomalies of gravity which exist in India even when no surface features are present to account for them.

Review of geodetic work in India

The earlier application of geodetic study in India was in the measurement of base lines and arcs of triangulations and astronomical observations of latitude. From this data Col. George Everest calculated his figure of the earth in 1830. Everest's figure has been used for the computation of the whole of the Indian triangulation with much benefit on the whole, allowing for a few slight discrepancies of no consequence. The following remarks of Brigadier Sir H. Couchman regarding its use are of interest :—

'The result of using Everest's spheroid as the reference figure for computing the elements of the Indian triangulation is that India occupies on its maps slightly more than its proper share of the earth's surface. In longitude, from Baluchistan to Burma, a distance of some 2,500 miles, this excess is about 2,500 feet. This excess will cause no embarrassment until our neighbours carry out independent geodetic triangulation and mapping up to our common frontier where each point on the ground will then have two values of latitude and longitude, our own and our neighbour's. Until there is a prospect of this, the immense labour of republishing all Indian maps on a corrected graticule is not worth undertaking. Siam is at present our only neighbour that has carried out accurate triangulation up to the Indian border, but as they have so far accepted the Indian values of latitude and longitude for their base station, there is no discrepancy in maps.'

'But whatever spheroid is used it is evident that it cannot absolutely represent the geoid. Excesses or deficiencies of matter and of density must distort the geoid from any purely mathematical form, and it is to this distortion, or as they are usually called separations, of the geoid from the assumed spheroid that considerable attention has been recently devoted in India.'

'As it is, India has been free from the difficulty experienced by many countries which have carried out detached surveys without a rigid framework of triangulation. Our difficulties have been relegated to the frontiers where they are clearly of less importance.' [1]

Isostasy hypothesis inadequate

During the period covered by the review, there has been a great revival of geodetic activity in India. The Geodetic branch of the Survey has accumulated a large volume of data of the values of the force of gravity of pendulum observations and the direction of gravity by astronomical means. It is these data and their interpretation to establish a satisfactory correlation with surface geology that have drawn attention to the insufficiency and weakness of the isostatic theory as propounded by Hayford. For the surface features of India, although a certain degree of compensation does

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[1] Progress of Geodesy in India, Presidential Address, National Institute of Sciences of India, Hyderabad, 1937.

exist (i.e., underneath the great heights there is a defect of density and an excess under the topographic depressions), there are serious anomalies between the theoretical and observed values of the direction and force of gravity which remain to be accounted for. The Gravimetric Survey has now definitely proved a deep-seated belt of excess of density underneath the plains—the Hidden Range of Burrard, running N.-W. and S.-E. of Jubbulpore from Karachi to Orissa. To the north and south of this are belts of defects of density. This irregular variation of density is inconsistent with the isostasy, which postulates that underlying excesses or defects of gravity must be reflected in surface deeps or heights. The brilliant gravity measurement work carried out by Col. E. A. Glennie during the last few years, from a large number of stations scattered over Northern India, has enabled him to explain provisionally the numerous gravity anomalies by assuming a series of upward bulges or downward warps or troughs in the sub-crust which may be taken to be some 10 to 20 miles below the surface. These crustal warps elevate or depress the denser, more basic layers of the sub-crust which underlie the lighter more acidic rocks of the surface crust, above or below their equilibrium plane. The theory is still in a stage of discussion but it promises to explain the residual anomalies in the force of gravity that are so commonly observed in India.

It appears that India as a whole is an area of defective mass. As judged by the international formula, gravity in India is in defect by an amount corresponding to 600 feet of rock over an area of 2 million square miles.

Crustal movement and continental drift.—Geodetic measurements can detect changes of position or level which accompany earthquakes or the much vaster secular movements due to continental creep. In India various observations have been repeated after an interval of time, but the evidence of crustal movement has generally been negative.

The astronomical longitude of Dehra Dun has been accurately determined on three occasions with the following results :—

1894	78° 2′ 56″·55
1926	78° 2′ 56″·25
1933	78° 2′ 56″·70

The probable error in each determination is $\pm 0''{\cdot}3$, and there is no suggestion of change.

No evidence of drift

Several astronomical latitudes have been repeated at different times, covering 100 years. The results have been collected, but the changes shown are irregular and provide no evidence of continental drift, on the postulates of Wegener's hypothesis, to the north or south. On the other hand, they are not adequate to disprove a movement of say 50 feet in a century.

Relevelling in Bihar after the 1934 earthquake revealed a sinkage of bench-marks of between 1 and 4 feet over a large area. Much of this was probably due to local sinking of the structures on which they were marked, and it is possible that all disturbances were of a similar purely local character, but there is some evidence of a general lowering of the surface by one or two feet.

Between 1905 and 1933 during a long series of observations from Mussoorie, there was no change of height noticed in four Himalayan peaks which are visible from that station.

Value of geodetic work

Geodetic work in India has a wide international appeal and has aroused much interest and curiosity in Europe and America for the last forty years. Its future progress will be watched with equal interest by geologists and geophysicists. The preliminary gravity survey is now nearly complete, but the results of the computation of the numerous data and their bearing on the geological structure of the country are not likely to be available for some time. So far the geodetic data are in the main in conformity with the results of geological investigations based on stratigraphic and tectonic work, both in Northern India and in the Peninsula.

Nor is this work devoid of practical uses. Results of practical value in seismology, location of underground deposits of water, oil, minerals and ores, and in the solution of structural problems, *viz.* detection of faults, etc. will be the outcome of well-co-ordinated schemes of geological, geophysical work in selected sites. Col. Glennie has already collected data of sub-soil water-levels in alluvial areas and the obstacles to free movement of ground water by submerged ridges of rocks, *etc.*, while in the Punjab a gravity survey revealed a chain of rock buried under the alluvium running north-west from Delhi to the Salt Range.

(c) *Geography in the Universities.*

Educational geography has made hardly any progress in Indian Schools and Universities. Educationists have been slow in realizing the value of geography in liberal education beyond the school stage. Only three or four of the Indian Universities have so far instituted Chairs in this subject, though there are signs of improvement in this direction and of other universities including geography among their curricula.

Besides some smaller school and college associations, there are two well-organized Geographical Societies in India which are serving a useful purpose in awakening the public mind to a proper appreciation of the value of geography—the most ancient of all sciences. The best known are the Madras Geographical Association, Madras and the Calcutta Geographical Society, Calcutta.

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THE PROGRESS OF AGRICULTURAL SCIENCE IN INDIA DURING THE PAST TWENTY-FIVE YEARS.

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Contents.

I. Introduction.

It is notoriously difficult to write history, particularly recent history, and it is hoped that the following account of the progress of agricultural science in India will be judged mercifully. Moreover, any treatment of agricultural science means the description of progress in a number of branches of pure and applied science

and this has made the work rather more difficult than a similar treatment of a single science. On the other hand, there has been no lack of material and it is the embarrassment of riches which has been more an obstacle than any paucity of facts.[1] Inevitably, therefore, there will be omissions both in the work described and the workers mentioned and it is hoped that all these defects will be overlooked and the picture considered as a whole.

The treatment of agriculture scientifically may really be said to have begun with the visit of Dr. J. A. Voelcker to India in 1889–1891. His report, entitled 'The Improvement of Indian Agriculture' published in 1893, is a valuable source-book of information and a datum line for estimating progress in ideas, in scientific discovery and in practice. The report is out of print but a few copies are scattered throughout certain libraries in India.

The occurrence and recurrence of famines in India had been the subject of the report of the Famine Commission in 1880. The Commission insisted strongly on the revival of the Department of Agriculture of the Government of India and on the formation in the provinces of Departments of Agriculture. The duties of these departments were to be largely connected with the collection of experience regarding past famines and of undertaking definite and permanent charge of the administration of famine relief. While in ordinary times the collection of facts relating to agriculture would be their routine duties, in a Government Resolution of December 8th, 1881, the duties of a Provincial Department of Agriculture were briefly defined as agricultural enquiry, agricultural improvement and famine relief. This remained the condition of things till in 1889 the Secretary of State for India sent out Dr. Voelcker, Consulting Chemist to the Royal Agricultural Society and as a result of his report and under the stimulus of Lord Curzon as Viceroy, the central and provincial Agricultural Departments of India in their present form came into being. Their aims, objects and personnel are described by Sly in the first number of the *Agricultural Journal of India* published in 1906. There had previously existed, since about 1904, an Inspector-General of Agriculture with a certain nucleus staff and a central body of research workers located at Pusa. As is described in detail in the various sections of this survey, this group of early workers at Pusa consisted of talented men who laid well and truly the foundations of agricultural research in India. Development in different provinces in India was somewhat unequal, but there *was* progress, and in the years 1908–1914 the Agricultural Departments really got going.

Then came the Great War and inevitably agricultural research was slowed up. A considerable number of agricultural officers

[1] Mr. N. V. Kanitkar, Chief Investigator, Dry Farming Research Station, Sholapur, has greatly helped me by writing parts of Section V 'Agricultural Chemistry'.

entered the Army or its attached forces and services in one capacity or another and one of their number Mr. E. B. Woodhouse, Economic Botanist to the Government of Bengal, died of wounds received in action on the 18th December, 1917. In his memory a Woodhouse Prize for an essay on an agricultural subject is yearly awarded. During the war, the Poona College of Agriculture was, with the exception of one block, turned into a War Hospital for the wounded from Mesopotamia. The playing field of the College was covered with additional temporary buildings to help in housing the very large number (about a thousand) of casualties that this hospital contained. The actual work of the College was carried on in the block intended for the chemical work only.

At the end of the war, there was naturally an expansion. Recruiting of agricultural officers was re-started and lines of work, which had been more or less in abeyance, were taken up again with enthusiasm. The period from 1919–1929 was one of considerable progress. During this period the Royal Commission on Agriculture under the Chairmanship of the present Viceroy, the Marquess of Linlithgow, visited India and its report, published in 1928, is another landmark in India's agricultural development. It has proved a most valuable résumé of agricultural facts and a source of guidance for development in all directions. The most striking result of the recommendations of the said Commission was the establishment in 1929 of the *Imperial Council of Agricultural Research*—a body which has grown in importance and beneficent influence and is now the great organizing and co-ordinating influence in agricultural research throughout India. Its composition is as follows :—

Imperial Council of Agricultural Research

(1) A *Governing Body* presided over *ex-officio* by the Hon'ble Member of the Government of India for Education, Health and Lands, and having as members Ministers holding the agricultural portfolios in the Provinces, certain Revenue Members, Diwans of States, a representative of the Council of State, two representatives of the Legislative Assembly, a representative of the Associated Chambers of Commerce of India, a representative of the Federation of Indian Chambers of Commerce and Industry, two representatives of the Advisory Board and Diwan Bahadur Sir T. Vijayaraghavacharya (a total of 29).

(2) An *Advisory Board* composed mainly of Directors of Agriculture, Directors of Veterinary Services and technical experts in various subjects plus certain University representatives and officers of allied departments and certain non-official members (total 63) ; and

(3) *Standing Committees and Sub-Committees for various subjects.*

The Imperial Council of Agricultural Research is a Department of the Government of India, the Hon'ble Member for Education,

Health and Lands being its head. It has a Vice-Chairman, an Agricultural Expert, an Animal Husbandry Expert, an Agricultural Marketing Adviser, a Secretary and an office staff. Its headquarters are at New Delhi from mid-October till mid-April and Simla for the rest of the year.

Indian Central Cotton Committee

So far as cotton is concerned a great stimulus was given to research when the *Indian Central Cotton Committee* was formed in 1921. This Committee, which is financed by a cess of two annas a bale on all cotton produced in India, meets twice a year in Bombay. It has numerous sub-committees of which the strongest is the Agricultural Research Sub-Committee which deals with all schemes put up for financing by the main Committee, while the Local and Finance Sub-Committees meet often and carry on business between the six-monthly meetings of the main Committee. It has also various other special sub-committees, of which the Technological Sub-Committee deals with that side of cotton research and the Technological Institute's work. Some of the work done under the ægis of the Indian Central Cotton Committee is mentioned later. Up to date the Indian Central Cotton Committee has spent over Rs.74,00,000 on research and Rs.9,33,000 on seed distribution.

Indian Central Jute, Indian Lac and Coffee Cess Committees, etc.

The recently formed *Indian Central Jute Committee* is playing a similar part in the financing and guidance of research and we have also in India the *Indian Lac Cess Committee* and the *Indian Coffee Cess Committee* both of which give money for research purposes. There are certain other funds such as the Sassoon David Trust Fund in Bombay from which money is available for agricultural research. The research work of the *Indian Tea Association* at Tocklai in Assam is outstanding and has grown from small beginnings under Mann in the early years of this century to its present highly developed condition under Carpenter.

The Imperial Council of Agricultural Research has endeavoured to arrange for the collaboration of the Indian Universities in branches of work connected with agricultural science in which they have special equipment or specially trained workers and to give subsidies for such work. Between the Agricultural Department and the Irrigation Department, the Forest Department and the Medical Department there is healthy liaison and collaboration on many border-line problems.

Agricultural Research Institute

Returning again to the landmarks of the past twenty-five years, another of these was the earthquake which severely damaged the Pusa Research Institute in January, 1934. It was decided by the Government of India to rebuild the Institute on another site and the result is the new Institute of Agricultural

Research built five miles from New Delhi. This has been described by the present writer in '*Nature*' (Vol. **139,** No. 3515, 13th March, 1937) and was opened by His Excellency the Viceroy on 7th November, 1936. Last and greatest event of all is the new constitution for India, which is now functioning in the various Provinces.

It has been an eventful twenty-five years !

II. Plant-breeding.

The establishment of the new Agricultural Departments in India took place only a year or two after the epoch-making re-discovery of Mendel's work on the inheritance of plant characters. The recently recruited Economic Botanists had all received some training in the new science and were keen to apply it to the practical problems of plant breeding in India. At the same time they were anxious to keep in touch with the rapid developments which plant genetics was undergoing in Britain, America and the Continent of Europe, and hence there has been throughout the whole twenty-five years a most salutary influence of pure genetics on practical plant-breeding and of practical plant-breeding on pure genetics.

It is not to be thought that there had been no effective plant-breeding previous to this period. There have always been in the Agricultural Departments men with a *flair* for plant selection and an eye for spotting winners. Some of the existing and still famous commercial varieties of Indian crops were produced in the very early days. One of these, for example, is the cotton 1027 A.L.F.—the longest-stapled *indigenous* Indian cotton strain, which covers about 3 lakhs of acres in the Gujarat Division of the Bombay Presidency and its associated States. The original cross from which 1027 A.L.F. was later selected was made by G. A. Gammie about 1900.

(*a*) *Cotton.*

Cotton has perhaps more than any other crop benefited from the work of the plant-breeders and there is no important cotton-growing province in India which has not, as the result of this work, several important improved commercial varieties which have greatly benefited the cultivator, the broker, the shipper and the manufacturer.

Punjab

In the Punjab, there has been the striking work of D. Milne in the selection of improved strains in the American Cotton crop, for the Punjab is one of the places where American cottons have found a footing and are important. The first variety was called 4 F. Later (about 1916-17) 285 F was also spread, while later still 289 F became and remains an important trade cotton. Among early Punjab-American strains,

bred by Trought. 43 F turned out well and is now given out for general cultivation. In Asiatic cottons a success has been recently scored by Mohammad Afzal with Jubilee Cotton (so called because released in 1935) which is a cross between the Chinese cotton 'Million Dollar' and *Gossypium Mollisoni*. Work is also in progress for the breeding of a variety resistant to Jassids and for this purpose a cross between Tanguis cotton and the variety known as U 4 is being studied.

United Provinces

In the United Provinces, the work was begun by H. M. Leake and in 1916-17 the hybrid K 22 showed prospects of being suitable for extended cultivation. Among the *Deshi* varieties, Aligarh white-flowered was popular. By 1919-20 a pure race C 49 isolated from Cawnpore-American was yielding well, K 22 was still to the fore and 5 NI, a selection from Bundelkhand cottons was giving good yields. By 1926-27 a new type C 402 was showing promise and a short-stapled cotton A 19 was distributed. In 1933, C 520 had also been added and C 402, C 520 and A 19 had become the cottons distributed by the Department. Quite recently an exhaustive survey of the cotton grown in Rohilkhand and Bundelkhand has been undertaken with finance provided by the Indian Central Cotton Committee, and a wide range of interesting material secured, as the basis of future selection.

Madras

In Madras, the cultivation of Cambodia cotton was started at Coimbatore in 1905. The inferior cotton 'Pulichai' was a menace 20 years ago and was only got the better of by drastic legislation, within the last 5 years. In cottons other than Cambodia selection produced Nandyal 14 and Hagari 25. Co 1 (previously Cambodia 295) proved to be of exceptionally high spinning value and Nandyal 14 remains an excellent cotton. Other Hagari cottons, such as H 25 and H 62 replaced Hagari 25. Karunganni 546 is a recent success in that kind of cotton.

Bombay and Sind

In Bombay, there are four main cotton areas. In the south a succession of plant breeders have succeeded in producing a very successful strain called Gadag I of the so-called Dharwar-American cotton *G. hirsutum* (a legacy from attempts made about 1840 to introduce American cotton) and also a strain of the Indian cotton variety called 'Kumpta' (*G. herbaceum*). This strain is called 'Jaywant', which means 'Victorious' and signifies that it defeated wilt (due to the soil fungus *Fusarium vas-infectum*). This was done by Kottur, who crossed his previous selection (Dharwar I) and another (Dharwar II) (in 1922), the latter cotton carrying the resistance. 'Jaywant' was fixed by 1926 and had spread over 2,00,000 acres by 1931. In the Khandesh area the local very mixed Khandesh mixture (mainly *G. neglectum*) was replaced first by a *roseum* selection, later by 'Banilla' (Bani × Comilla), a cross between *G. indicum* and *G.*

cernuum and is likely to be in its turn succeeded by a very successful *verum* selection (produced by Prayag), and (now called 'Jarila') which has a $\frac{7}{8}''$ staple. In South Gujarat the already mentioned 1027 is the dominant cotton and in North Gujarat which has rather severe climatic conditions special studies are now being made of close-bolled cottons suitable for that area. In Sind (now an independent province, but for long a part of the Bombay Presidency) a very successful American selection, Sind Sudhar, has been evolved, while an Asiatic selected strain 27WN surpasses in gross yield every other type tried.

Central Provinces

Cotton breeding in the Central Provinces was first largely directed to the development of *roseum* strains, but in recent years has been more and more concentrated on the *verum* sub-variety, from which Youngman produced Verum 262, and in recent years Mahta has evolved a Late Verum, a V 434 and also a V 438 suitable for lighter soils.

Research

Under Hutchinson's guidance and stimulus much work has recently been done at the Indore Institute of Plant Industry on the genic analysis of Indian cottons, and on the relationships in time and space of Indian cottons to the other cotton species of the world. This is linked up with the cytological work of Skovsted in Trinidad. At Indore also there has been a considerable development of plant-breeding technique, particularly in devising methods for getting statistical significance from early stages of selections and crosses.

The establishment by the Indian Central Cotton Committee of a Technological Laboratory in Bombay has been of the greatest advantage to plant-breeders as it has enabled them to get an early estimate of the spinning qualities of their newly evolved strains, so that these strains, however apparently satisfactory from the point of view of staple, ginning percentage, and yield, can be discarded if they do not show up well in the actual production of yarn.

Very important advances have been made in the production of cotton races immune or highly resistant to wilt disease, due to the fungus *Fusarium vas-infectum*. This is definitely a case where theory and practice have gone hand in hand to the dual goal of a completely immune cotton and a better understanding of the nature and method of the inheritance of wilt resistance. This subject was a special theme of discussion at the first meeting of Scientific Research Workers on Cotton in India held in Bombay in March, 1937, and the results of their discussions are crystallized in the following statement which was passed unanimously at that meeting :

'This Conference agrees that the breeding of strains immune to wilt under optimum conditions is the ideal to aim at. For agricultural distribution resistance of the order of 95% under heavily infected field conditions is satisfactory, provided that the strain has been tested and shown to be practically homozygous for that degree of resistance to wilt.

The Conference recommends that :—

(1) tests for homozygosity should be applied before a resistant strain is released for distribution,

(2) the Pathologist should also conduct tests for homozygosity and need only select in material shown to be heterozygous, and

(3) the conditions under which field tests are being carried out should be described and standardised as far as is practicable.'

(b) *Wheat.*

Another crop on which a great deal of work has been done is wheat. The early work on this subject was done by Sir Albert Howard and the late Mrs. Gabrielle Howard. These two workers had in a very high degree the ability to select in the field plants that afterwards proved exceedingly useful and the range of Pusa wheats so evolved is a long one. Most of them have been fully described in the *Memoirs of the Department of Agriculture* (Botanical Series), and several of them have spread outside India and have been found useful, particularly in Australia. The best known and most widely spread varieties in India are Pusa 4, Pusa 12 and Pusa 52. Of wheat strains produced in recent years Pusa 111 has been pronounced equal in quality to the best Canadian wheat and Pusa 114 has proved successful on the Lloyd Barrage lands in Sind on account of its disease resistance and quality. In Sind itself the local plant breeders have produced HSW III and CPh 47 both very suitable for that province. In recent years crosses between Federation and Pusa 4 and Federation and Pusa 52 have been promising. Wheat breeding was also carried on vigorously in the Punjab (India's premier wheat growing province) by D. Milne and his successors with the result that the Punjab has now a range of characteristic and useful wheat varieties produced in that province. Some of the early successes were Punjab 11 and selection 8A, the latter still a very widely grown wheat. Recent research has now enabled the Punjab Agricultural Department to offer Cross 518, a high-yielding wheat for rich land and good water supply and Type 9D for poor land, poor irrigation and late sowing. Cross 591 is another recent success. It has an attractive grain and makes excellent ' Chapatis '.

In Bombay, wheat breeding work started rather later and has been concerned mainly with the *durum* wheats. The workers were Chibber, Bhide and Kadam. This work was first done at Poona, but later shifted to Niphad in the centre of the Nasik-Khandesh wheat area. Strains 162, 168 and 224 have been successes. Hybrids between the local Bansi wheat and Khapli (*Triticum diococum*), now called the ' Bansipalli ' wheats, have given good

yields along with considerable rust resistance. Of these the best known is 808, an early maturing strain.

In the Central Provinces plant breeders have produced the 'Sherbati' wheat strains A 113 and A 115, and the latter has also been crossed with Australian and Palestine wheats giving some fairly rust-resistant strains suitable for the north of the province.

Wheat Rust

As in all countries where wheat exists, the problem of wheat rust due to various species of the fungus *Puccinia* is always present and from time to time acute. India is fortunate in possessing one very highly resistant wheat species, viz., *Triticum diococcum*, known in Indian languages as 'khapli', and this has been used as a parent in many of the crosses that have been made to introduce rust-resistance into Indian wheats. The problem of rust-resistance is, however, a very complex one, since not only are we dealing with three different species of rust (*P. graminis*, *P. glumarum*, and *P. triticina*) but it has been shown that in each of these there are physiologic races which resemble one another in external characters but differ in the wheat varieties or strains which they will attack. In America, the work of Stakman and others has shown that there are over 150 physiologic races there of the black rust *Puccinia graminis*. In India so far only 6 have been identified with certainty but even these present a very considerable problem. The Imperial Council of Agricultural Research has for the last eight years been subsidizing a comprehensive research on the question of rust distribution and rust-resistance in India. This has been in the hands of K. C. Mehta, Professor of Botany, University of Agra and his staff and the results up to date have been instructive. The main conclusion is that the persistence of rust from year to year is not due to the barberry but to the oversummering of the disease on volunteer and early-sown wheat in hill areas throughout India. Certain infection foci have been located and their responsibility for outbreaks in the plains traced by means of wind charts. Wheat breeding, with the special aim of producing rust-resistant varieties, particularly for the hills, is in the hands of B. P. Pal of the Imperial Agricultural Research Institute.

(c) *Rice.*

Probably the most important food crop throughout the greater part of India is rice, and it is natural that the attention of the Economic Botanists in the rice-growing provinces should have been early devoted to this important cereal. Hector in Bengal, Parnell in Madras, Bhide in Bombay and many others laid the foundation of the production of important and useful varieties and also contributed largely to our knowledge of rice genetics. Inheritance of colour, of awn peculiarities, of habit and of various other characters have been thoroughly studied and these results linked up with what has been done in various other rice-growing countries

such as Japan, the United States of America and the Philippines have produced a great body of knowledge of both theoretical and practical importance. At the present moment rice research is being carried on with more vigour than ever largely due to the fact that the Imperial Council of Agricultural Research is subsidizing a chain of rice research stations throughout India. These are located at Bankura, Suri and Chinsura in Bengal, Berhampore in Orissa, Sabour, Gaya, Kanke and Cuttack in Bihar, Nagina in the United Provinces, Raipur in the Central Provinces and Habiganj in Assam.

The number of rice varieties cultivated in India is legion, and out of these there have been produced by selection and hybridization many more. Systems of classification of rice varieties have at various times been attempted. The question, however, is now in process of solution by a more scientific method, largely due to the suggestions of Hutchinson (who left India for Trinidad in 1937). What is now being attempted is not a taxonomic classification in the old style but a study of variability in the species and the drawing up of a schedule for description with appropriate colour charts. A special sub-committee of the Imperial Council of Agricultural Research has been dealing with this question in rice and another in cotton.

In the United Provinces success has recently been attained by R. L. Sethi in evolving a rice strain immune to the attack of the rice fly (*Leptocorisa varicornis*) by breeding into a good-quality rice the morphological character of a 'flag' (sheathing leaf) which continues to enclose the earhead during its existence. In Bombay the earliest success was a variety known as Kolamba 42 suitable for the central rice-growing areas. For the southern districts various other rices have been evolved. In Bengal various improved strains were an early result of the Department's activities and also in Madras. In the latter place the application of X-rays has recently given some remarkable mutants and cytological studies are being combined with a breeding programme.

Wild rice has always been a problem, as it hybridizes easily with cultivated rice and transmits to the progeny its evil habit of ear-shattering and dropping its seeds in the mud. Attempts to deal with this by breeding have been carried out in many provinces. The Central Provinces has done it by breeding colour into its selected rices for districts where wild rice is a pest, so that the wild (non-coloured) rice can be rogued out in the seedling stage.

To criticise programmes, to study results and to help in deciding policy, there is a Standing Rice Committee of the Imperial Council of Agricultural Research which has had a great and beneficial influence not only in co-ordinating research work but also in making sure that research work takes account of the needs of the cultivator and the trade.

In Burma, now politically separated but until last year a part of India, the work on rice has also been carried on by a succession

of able botanists (the most recent being Grant) and in Burma attention has been directed, amongst other things, to the production of varieties suitable for the English market and able to compete with the Spanish types which are popular there. This problem has been solved through hybridization, the well-known American variety Blue Rose having proved a useful parent.

(*d*) *Millets.*

Of great importance to India as food for both man and beast are the millets, of which the grain is used for human food and the straw is the main sustenance of cattle. The most important millet is that which is known over the greater part of India as *jowar* and in Madras as *cholam* (*Sorghum vulgare*). There exist an enormous number of well-marked races of sorghum and, within some of these, straightforward selection has given excellent results so that in various provinces varieties with a departmental name are now distributed as part of the provincial programme. Such are Budh Perio 53 in the Surat District of the Bombay Presidency, EBI and 123A in the Central Provinces and J 8 in the Punjab. There is a Millet Specialist in Madras whose studies in the inheritance of various characters in sorghum have been a feature of various scientific journals in the past five years, and whose plant breeding work is shown by the distribution of many improved strains, e.g., all the AS strains. In the Punjab a Fodder Specialist looks after *jowar* as a fodder plant along with other species.

Another important millet is *bajri* or *bajra* (*Pennisetum typhoideum*) sometimes referred to as the 'pearl millet' outside India—a crop adapted to poor soils and low rainfall and giving a nutritious grain and a useful straw. This crop is very markedly cross-fertilized due to the fact that the stigmas emerge before the anthers and hence it offers a rather difficult problem to the breeder. The evolution of new varieties has been undertaken in Bombay and Madras. *Ragi* (*Eleusine coracana*) is one of those poor millets not far removed from the wild grasses and grown mainly on poor hill lands in heavy rainfall areas. In Mysore, Madras and Bombay its breeding has been carried on, and also studies made in its genetics.

(*e*) *Oilseeds.*

Various oilseeds have received a fair amount of attention from plant-breeders. *Groundnut* is not indigenous to India. It was introduced years ago but spread with great rapidity. The total area under groundnut in India now amounts to 7,211,000 acres, Madras having by far the greatest area, viz. : 3,427,000 acres, Bombay (including Indian States) coming next with 1,752,000 acres. Various types of groundnuts have been from time to time introduced but a systematic attempt to improve groundnut by

breeding is of comparatively recent date and has been finally concentrated in a scheme of groundnut improvement financed by the Imperial Council of Agricultural Research and located in Madras. In Madras the improved variety AH 25 was distributed for the first time in 1935. It is drought-resistant and yields 15 to 20% more than the local spreading varieties. Interspecific hybridization has been carried out between *Arachis hypogea* (the commonly cultivated groundnut) and *A. Nambyquaræ* and *A. Rosteriro*, two Brazilian wild species.

Another important oilseed in India is *castor*. Work on the selection of castor was undertaken in Bombay by Burns and Masur about 1922. Stating from a range of varieties, which were known to be commercially suitable as regards size and colour of seed, an attempt was made to select varieties for yield and for oil-content. This has resulted in the evolution of one or two definitely improved types. Recently, however, this type of work has been put on a firmer basis by a grant from the Imperial Council of Agricultural Research and is now located in the main castor-producing area of India, viz., Hyderabad State. There is an Oil-seeds Specialist in Madras who also deals with this crop and has evolved high-yielding lines and done a botanical classification of castor.

In the Punjab, there are several species of *Brassica* all of which are important as oil-seeds and also in the rotation programme of Punjab agriculture. These are *Rai* (*Brassica juncea*) *Sarson* (*B. campestris* var. *Sarson*) *Toria* (*B. Napus* var. *dichotoma*). They offer an extremely difficult set of problems. It is quite probable that some of these species are not valid and it is necessary to determine the real genetic groups, and, thereafter, intra-varietal variability. The matter is complicated by wide-spread self-sterility, though the Punjab plant breeders have been able to produce one or two self-fertile races.

(*f*) *Sugarcane*.

No discussion on plant-breeding in India would be complete without a reference to what is perhaps the most spectacular work of all, viz., the production of new sugarcane varieties centred at the Sugarcane Breeding Station at Coimbatore. This station was started by Barber in 1912 and has been carried on since his departure from India by T. S. Venkatraman, Imperial Sugarcane Expert. From this station there has issued a continuous stream of new varieties of so-called 'Co'(=Coimbatore) varieties which are now widely known throughout all countries where sugarcane is grown. There is now, we may say with truth, a Co cane suitable for every situation in India where sugarcane will grow. This work has not only produced these important practical results but has been a mine of scientific discovery. There was in the first instance, the finding out of how sugarcane could be crossed and hybrid seedlings produced. In the course of such crossing certain wild

species of cane have been used as parents in order to bring in toughness of constitution and resistance to disease. The study of these wild species has revealed among them an astonishing range of forms. Not only has sugarcane been crossed with its wild relatives but it has also been crossed with sorghum and in the past year with bamboo! The sugarcane-sorghum hybrids have given a series of types with their own peculiar characteristics. What will come out of the sugarcane-bamboo cross still remains to be seen. Associated with this work is an intensive study of the cytology of sugarcane species and hybrids and of the sugarcane-sorghum and sugarcane-bamboo hybrids, and these studies have given important indications as to the evolution of many forms.

(g) *Miscellaneous.*

Chilly

It is impossible to deal fully all the various crops which have been handled by the breeders, but two may be mentioned in conclusion as these have offered a considerable amount of interesting scientific data. The first of these is the 'chilly', *Capsicum frutescens*, in which species the inheritance of characters was specially studied by the late F. J. F. Shaw and by R. B. Deshpande at Pusa. Some of the interesting results obtained from this work are: (1) that the purple colour of the plant is due to two factors one of which is a basal character and the other an intensifier; (2) that the pendent condition of the fruit is dominant to the erect, and that in a plant heterozygous for this character variations in fruit position may occur on the same plant; (3) that the length of fruit is probably inherited on a trihybrid basis and thickness of fruit on a mono-hybrid basis, and (4) the F_1 shows heterosis in several characters.

Sann Hemp

The other scientifically interesting crop is Sann hemp (*Crotalaria juncea*), the breeding of which had to be taken up in Bombay by B. N. Uppal in order to get a variety resistant to wilt which was beginning to be a serious pest in the canal districts of the Deccan. Since Sann hemp is the main green-manuring crop for sugarcane in the Deccan, such a disease constituted a real menace to cultivation. This crop offers peculiar difficulties in obtaining self-fertilized seed. In nature it is normally cross-fertilized by very large solitary bees and a special technique had to be invented in order to obtain self-fertilized seed.

Potatoes

The early work on potatoes of the Agricultural Departments was devoted mainly to disease problems, including storage rots. Breeding started when the Imperial Council of Agricultural Research in 1933 and 1935 financed schemes for Madras and Northern India respectively. A valuable collection of S. American species of Solanum has been built up with the aid of the Imperial Bureau of Plant Genetics and research

workers in the U.S.A. and the U.S.S.R. and these species will be used as source of new genes for the improvement of the Indian crop.

Looking back over the twenty-five years, one can recognize: (1) an early period of rapid successes due to the wealth of unselected material available to plant-breeders; (2) along with this the first gropings towards the interpretation of inheritance phenomena by applying the knowledge then available concerning genetics; (3) a period when marked improvement particularly in yield was difficult to get and when knowledge of genetics was growing; and (4) a second period of rapid progress due to the greater applicability of modern genetical knowledge and bolder conceptions of what could be obtained by bringing in new genes from distantly related and often wild species.

III. Plant Diseases due to Fungi.

Mycology as a separate science was fairly well established in Europe twenty-five years ago and there was at least a very considerable foundation of knowledge and technique for starting mycological work in India. For a long time, however, effective mycological investigation was more or less confined to the Pusa Research Institute and it was only a good deal later that the provinces provided themselves with separate mycologists. In the early days, the Economic Botanist in each province was responsible for practically everything connected with crop plants outside their purely agricultural aspect. The writer of this note, for example, in his early service, dealt not only with economic botany in its narrower sense but also with plant-breeding, horticulture and mycology, in addition to being Professor of Botany at the College of Agriculture, Poona. In the same Department (Bombay Department of Agriculture) in addition to the Economic Botanist, there are now a Horticulturist, a Plant Pathologist and a Crop Botanist, numerous cotton breeders and one or two other special plant-breeding appointments such as a tobacco breeder. The first province to have a mycologist of its own was Madras where McRae began separate mycological work in 1909-10.

At the Central Institute at Pusa E. J. Butler was appointed as Imperial Mycologist and he laid most truly the foundations of mycological research in India. He made a very complete collection of fungi from the whole of India, identified these and made readily accessible information regarding them. He produced an important work 'Fungi and Disease in India' which has been and is a standard work on this subject. With unerring eye he picked out the wilt diseases of certain crops such as cotton, indigo, pigeon-pea and gram for special study and the work which he began on these has been carried to practical success

and great use by succeeding workers. The sugarcane Red Rot disease due to *Colletotrichum falcatum* received his early attention. This work was also followed up by others and the nature of its transmission through diseased setts and its consequent control by rejecting these has become so established that it has now ceased to be a really threatening disease of sugarcane in India. Another important disease to which he gave a great deal of attention in the early days was the coconut palm disease in the Godavari Delta. This work was later taken over and carried to a successful conclusion by McRae. The causal fungus was *Phytophthora palmivora*. It attacked most severely the palmyra palm (*Borassus flabelliformis*) the coconut (*Cocos nucifera*) less and the areca palm (*Areca catechu*) least, while the wild date palm (*Phœnix sylvestris*) was immune. The disease took the form of a budrot and according to McRae was spread by tappers and by the rhinoceros beetle (*Orycte rhinoceros*). Control measures consisted in cutting off and burning the tops of diseased palms and the application of Bordeaux mixture to the leaf sheaths within a 25-yard radius of a diseased palm. A campaign on these lines was decidedly successful.

Twenty-five years ago, the first investigation of Tea Blights was done by Butler and McRae. In Mysore L. C. Coleman had already begun his important work on the diseases of the areca palm and published it as Bulletin No. 2 of the Mysore Mycological Series. Koleroga is due to the fungus *Phytophthora omnivora* and its life-history and treatment were worked out by Coleman and the treatment applied with success in Mysore and also in the neighbouring parts of the Madras and Bombay Presidencies. Koleroga is still with us and is not yet completely under control in some areas but this is more to deficiencies in propaganda, personnel and material than to lack of knowledge as to how to deal with the pest. At the same time there *are* certain gaps in our knowledge and these are now being filled by a specially financed research applied to this end under the control of the Plant Pathologist to the Government of Bombay (B. N. Uppal). Butler, in the course of his work in 1911-12 made a most important discovery that paddy affected by the disease called Ufra had always present in it an eelworm (*Tylenchus angustus*) and in later years he established that this eelworm was the real cause of the disease and devised methods for its treatment. The eelworm is amazingly resistant, being able to live at least 8 months if fully dried and 2 months if fully immersed in water.

Groundnut in its early years used to suffer a great deal from the so-called Tikka disease due to *Cercospora* species. This caused a great decline in the crop between 1894 and 1902 but by 1911-12 the disease had practically disappeared in Bombay due to the introduction of new varieties. Another soil fungus, *Rhizoctonia*, received attention from Shaw and the work on it was published as *Botanical Memoir*, Vol. 7, No. 4, 1914-15. The powdery and downy mildews of the grape vine received special attention in the

Bombay Presidency from Burns. The use of Bordeaux mixture with soap then started by him, rapidly became a standard procedure in the Nasik grape gardens until partially superseded by sulphur dusting due to Uppal's work in recent years.

As late as 1915-16 there were only five mycologists working in India, two of whom were located at Pusa, one under the Indian Tea Association, one at Mysore and one in Madras. At that time the Second Mycologist in Pusa was the late F. J. F. Shaw who was responsible for much of the early work on *Rhizoctonia*. In 1915-16 G. S. Kulkarni (now retired) then Assistant Mycologist of the Bombay Department completed a detailed study of the smuts of *Jowar* (sorghum) in Bombay. These smuts are *Sphacelotheca sorghi*, *S. cruenta*, *Ustilago reiliana* (*Sorosporium reilianum*) and *Tolyposporium filiferum*. He started the copper sulphate treatment of seed which held the field until the more recently developed cheaper and less troublesome method of rubbing the seed in powdered sulphur replaced it. All the sorghum smuts are not amenable to this treatment but fortunately the two that are widely spread and serious (due to *Sphacelotheca sorghi* and *S. cruenta*) are completely mastered by the sulphur treatment.

A disease of rubber known as the Black Thread disease was studied by Shaw, Dastur and McRae. The causal organism was finally determined as *Phytophthora meadii*, n.sp. by McRae (1917). As remedial measures Dastur recommended thinning out thickly planted trees, removal of diseased fruits and cessation of tapping of diseased trees. In Travancore, McRae and Sundaraman found that rot of the renewing bark could be checked by smearing the affected parts with a mixture of tar and tallow. Potato diseases (particularly storage rots) came in for a good deal of attention in Bombay from Ajrekar and Kulkarni during the war when the normal supplies of Italian seed potatoes were stopped. The most common rot-fungi were two species of *Fusarium*, *Sclerotium rolfsii*, and another species of *Sclerotium*.

Other mycological investigations at Pusa were the various diseases of apple trees in Kumaon, a sclerotial fungus attacking the Rangoon bean, the mildew (*Erysiphe Polygoni*) attacking the opium poppy in Central India, wilt disease in *rahar* (*Cajanus indicus*) and root-rot of the sal tree (*Shorea robusta*). Up to 1918-19 Madras still continued to be the only province with a mycologist. The proposals for appointments in the United Provinces, Central Provinces and Bombay were then under consideration. A sectional meeting of mycological workers in India held at Pusa in February, 1919 called attention to the neglect of mycological science in Indian Universities and emphasized the importance of the subject in India. On the recommendation of the same meeting, the Government of India agreed to participate in the Scheme for the establishment of an Imperial Bureau of Mycology in England and to contribute a sum towards its upkeep.

A rice disease known as Blast caused by *Piricularia oryzæ* was studied by McRae and an account published in the *Agricultural Journal of India*, Vol. **14**, Part 1, 1919. A disease of jute known as Black Band due to *Diplodia Corchori* Syd. engaged the attention of Shaw, Second Imperial Mycologist. In 1919-20 the study of species allied to *Helminthosporium* was taken up at Pusa. These are found commonly attacking maize, jowar, bajra, rice, wheat and oats, barley and sugarcane. This is one of the fungi in which it was found there was no specialization as regards hosts. Smut on *ragi* (*Eleusine coracana*) called for serious notice in Mysore for the first time in 1921-22. In that year also the first direct and conclusive evidence was obtained that the spike disease of the Sandalwood tree is carried from tree to tree through root connections.

In 1923-24, work on the identity on the fungus causing stem rot in jute was brought to a conclusion. The fungus which had been identified in Japan as *Macrophoma corchori* appears to be identical with that which has been worked within this country as *Rhizoctonia solani*. The incidence of this disease has been found to be largely dependent on the amount of potash available in the soil.

The virus disease of sugarcane known as mosaic drew attention about 1925-26 and this work has been continued and increased. Special research on sugarcane diseases is now financed by the Imperial Council of Agricultural Research and a great proportion of this work is done on the mosaic disease. Virus diseases generally are also the subject of a subsidy by the Imperial Council of Agricultural Research and this work is in charge of B. N. Uppal, Plant Pathologist to the Government of Bombay.

The very important and highly cultivated *pan*—betel vine—(*Piper betle*) is subject to various fungus diseases which have been investigated in Bombay, the Central Provinces, Bengal and Burma. The plants wilt and die due to one or more soil fungi and of these *Phytophthora parasitica* is one. Good drainage is the first essential for overcoming this disease and in Bassein (Bombay Presidency) the treatment of the roots with Bordeaux mixture was successful.

The very important rust disease of wheat has always received attention both at the Centre and in the Provinces. Bulletin No. 1 of the Imperial Department of Agriculture by Butler was entitled 'The Indian Wheat Rust Problem' and in 1906 Butler and Hayman published a much fuller account in a memoir. The following year Butler published an interesting paper. Observations on the susceptibility or resistance of wheat have always been carried out at Pusa and there was some early work in Bombay by Burns on the method of carryover of rust from one year to another by the so-called volunteer wheat, i.e., stray plants growing in the off-season. The Imperial Council of Agricultural Research has since 1930 financed an important work under K. C. Mehta on the study of wheat rust and its dissemination (see also Plant Breeding, Section II).

In 1929-30 a new Bunt of wheat (*Tilletia indica*) was discovered by Mitra in the Punjab. A simplified hot water treatment for the control of loose smut was successful in the Punjab in preventing this disease. A later development of this treatment received the Sir Ganga-Ram-Maynard Prize of Rs.3,000 in 1937. This method is the invention of Professor Jai Chand Luthra of the Lyallpur Agricultural College.

The disease or group of diseases of cotton known as root-rots have been recently under study in researches financed by the Indian Central Cotton Committee. In Gujerat, Likhite's results indicate that the affected cotton roots contain the organisms *Macrophomina phaseoli*, *Nemas* and some *Fusaria*. In the Punjab, on the other hand, Vasudeva's work indicates that the rot there is due to *Rhizoctonia bataticola* and *R. solani* acting together, their activity increasing in proportion to the amount of irrigation, while they are harmless to the cotton crop grown under rainfed conditions.

In Bombay a curious disease of cotton to which has provisionally been given the name of Small Leaf disease by which the whole or part of the plant is stunted, the leaves are reduced and sterility ensues, was examined. There was some evidence that the disease was due to a virus but research was discontinued as it did not appear to be of sufficient commercial importance for further expenditure.

Diseases of citrus have received attention in Bombay from Uppal and his colleagues. They have found that gummosis of citrus there is due to *Phytophthora palmivora* (the first time this fungus has been recorded as causing gummosis and brown rot of citrus). They have also discovered a Fusarium apparently responsible for a dieback of the *mosambi* orange. It may be mentioned in parenthesis that dieback may be due to a number of causes, some physiological, others due to organisms and no certain remedy can be recommended for any case of dieback till the cause or causes are better known. Diseases of citrus were also studied in the Punjab by Chaudhuri in 1930–35 (an investigation financed by the Imperial Council of Agricultural Research). These included wither-tip anthracnose (caused by *Colletotrichium gloeosporioides*), chlorosis and diseases due to saprophytic moulds. Bordeaux mixture with ferrous sulphate as a sticker proved a useful treatment.

Plant diseases due to bacteria began to be investigated in 1909 by the Imperial Agricultural Bacteriologist at Pusa including bacterial diseases of wheat, poppy and citrus.

In 1914 there was passed the Destructive Insects and Pests Act controlling the import into British India of living plants likely to bring in diseases or pests. In 1917-18, there was passed an order under the Destructive Insects and Pests Act by which no plant could be imported into British India through the letter or sample post and the importation of plants other than fruit and vegetables intended for consumption, potatoes and sugarcane

were restricted to certain prescribed ports where fumigation with hydrocyanic gas could be carried out. Import of plants by air is also absolutely forbidden. The Act and Rules are now again being examined to bring them up to date.

At the Indian Science Congress held in Calcutta in 1935, the presidential address (by J. H. Mitter) to the Section of Botany took the form of a very complete summary of past and present work in India on mycology and plant pathology, and the present writer has borrowed freely from that address.

Among phanerogamic parasites attention has been given specially to *Orobanche* (a serious pest of tobacco) and to *Striga* (a pest of sorghum and to a less extent of sugarcane). Some of Shaw's early work was on *Orobanche*. *Striga* has been investigated in more than one province. The Imperial Council of Agricultural Research is at present financing a research on *Striga* which is being carried on by Kumar at Poona. He has succeeded in showing *in vitro* that the germination of *Striga* seeds is due to a chemical stimulus from the host root, and is working towards the development of resistant strains. There is already one sorghum variety in Bombay, called Bilichigan, which has a certain degree of resistance. At Coimbatore in Madras Presidency the Millet Specialist is also studying the resistance problem.

IV. Insect Pests of Crop Plants.

Taxonomic work in Entomology had been carried on by the officers in charge of the Entomological Section of the Indian Museum since the foundation of the Museum in 1866, but it was not till about 1888 that the Government of India, recognizing the importance of the study of various crop pests, arranged with the Trustees of the Indian Museum for the determination of various pests by the Entomologists attached to the Indian Museum. As a result, two parts of a publication entitled 'Notes on Economic Entomology' were published by the Trustees of the Indian Museum under the editorship of E. C. Cotes. In 1899 the name of the publication was changed to 'Indian Museum Notes'. This was published at irregular intervals under the authority of the Government of India, Revenue and Agriculture Department, and issued by the Trustees of the Indian Museum. Five complete volumes and the first number of Vol. VI of this serial were published up to 1903. The last number of Vol. V was issued under the editorship of Lionel de Nicéville who was appointed Entomologist to the Government of India on 19th January, 1901, and attached to the Indian Museum. On the establishment of the Imperial Agricultural Institute at Pusa in 1904, the post of the Entomologist to the Government of India was transferred to the new Institute and his designation was changed to 'Imperial Entomologist'. With this change, the publication of the 'Indian Museum Notes' was dis-

continued and the work in reference to the Indian insect pests was also transferred to Pusa.

Maxwell-Lefroy started work in India in 1902. He was first stationed at Surat in the Bombay Presidency for work on cotton pests, and in 1904 was transferred to Pusa as the first Imperial Entomologist in the newly started Imperial Agricultural Research Institute. In addition to many papers and memoirs he produced two important books. The earlier one was largely practical and was entitled 'Indian Insect Pests'. The second was a comprehensive description of all the important known insects of India, under the title 'Indian Insect Life'. This is still a standard work. A somewhat similar publication entitled 'Some South Indian Insects' was later produced by Bainbrigge Fletcher, Government Entomologist in Madras (who later succeeded Maxwell-Lefroy as Imperial Entomologist at Pusa). Just as in mycology, the provinces were much later than Pusa in appointing Entomological Specialists, Madras making its first appointment in 1912. The Punjab appointed an Entomologist in 1919 and the United Provinces in 1922. In Bombay entomology has been carried on in some form or other since Maxwell-Lefroy's time, and the Poona College of Agriculture has at present a Professor of Entomology who is the headquarters expert. Early work in India naturally consisted in collection and classification. This was started by Maxwell-Lefroy and has been continued by all the Imperial Entomologists since his time with the result that the Imperial Agricultural Research Institute (New Delhi) now has a large, representative and well-cared-for collection.

The rearing of insects (especially those affecting crops) and the study of their life-histories went on hand in hand with classification and have been the subject of many illustrated papers and memoirs, a large number of these in recent years, coming from H. S. Pruthi (the present Imperial Entomologist) and his staff. Finally, the devising of control measures has been the necessary and logical outcome of these scientific studies. A short account will now be given of progress made in the last twenty-five years in connection with certain types of insects.

(*a*) *Locusts.*

The locust species which threatens India is the Desert Locust, *Schistocerca gregaria*, and in the last quarter-century there have been serious invasions in the years 1912, 1913, 1926, 1930 and 1935.

A discovery of fundamental importance due to Uvarov is that the Desert Locust exists in two phases—solitary (*solitaria*) and the swarming (*gregaria*). For years it may exist in the solitary stage, but when conditions favour its rapid multiplication, it changes into the swarming phase, and is then different in colour, body proportions and habits. It is in this phase that it is seized with that

restlessness that sends it in colossal swarms across enormous distances to be a dreadful visitation to man and his crops. At its 15th meeting held in December, 1929, the Board of Agriculture recommended (1) the establishment of a Locust Intelligence Bureau, (2) investigations on locust control measures, (3) a survey of the permanent breeding grounds in India, and (4) investigations into the bionomics of the Desert Locust.

In the eight years that have passed since then all these recommendations have been carried out. A Standing Committee of the Imperial Council of Agricultural Research was formed to deal with the locust question, and funds liberally supplied by the Imperial Council of Agricultural Research, the special Locust Research Staff costing Rs.5,13,353 during the seven years beginning December, 1930, the Central Locust Bureau costing Rs.39,740 and the Punjab Research Scheme on the biology and bionomics of the Desert Locust costing Rs.37,817.

The special Locust Research Staff under the Locust Research Entomologist (Ramchandra Rao) has its headquarters in Karachi, with outposts in the deserts of Sind, Baluchistan and Rajputana. At all these places intensive surveys have been made and continuous meteorological data collected. The ecology of the Desert Locust has been closely studied. The locust is sensitive to changes in its environment, but most of all to rainfall. Breeding occurs only when rain brings about the required degree of wetness in the desert soil. There is strong evidence that the seasonal appearance of locusts of the solitary type on different breeding grounds is due to their migration from one rainfall zone to another with the change of the seasons.

The work at the Punjab Agricultural College by the Government Entomologist there (M. Afzal Husain) on biology and bionomics has yielded interesting results especially as regards factors responsible for the development of the *gregaria* coloration in hoppers. *Solitaria* hoppers when reared crowded assume *gregaria* coloration, and *vice versa*. Isolated *solitaria* hoppers, when made to undergo muscular exercise, or reared in an atmosphere containing an excess of carbon dioxide, assume *gregaria* coloration. It has also been found that locust eggs remain unhatched and retain their viability for a long period if the soil is deficient in moisture, even if the temperature is favourable.

There were two serious locust visitations one in 1881–84 and one in 1902–04 of another species of locust, i.e., the Bombay Locust (*Patanga succincta*). Maxwell-Lefroy and the Bombay Government Agricultural Department handled the 1902–04 attack and there has never been a recurrence.

(*b*) *Cotton Pests.*

Insects attacking cotton have always received a good deal of attention and the Indian Central Cotton Committee has spent a

great deal of money on the financing of research and propaganda schemes in connection with such pests. The Spotted Bollworm (*Earias insulana* and *Earias fabia*) and the Pink Bollworm (*Platyedra gossypiella*) are such pests.

Spotted Bollworm

The main work on the Spotted Bollworm done at Surat was published in the Imperial Council of Agricultural Research Monograph No. 10, 'The Spotted Bollworms of cotton in Southern Gujarat', by Deshpande and Nadkarni (1936). The main result of this research was that the pest has no period of æstivation and requires live cotton plants (or alternate hosts such as certain wild and cultivated Malvaceæ) all the time. Hence if it can be arranged that there is a period when no cotton plants are on the ground the pest should be greatly diminished. This again resulted in the devising of a special plant-puller (like a magnified nail-puller) to take the cotton plant out of the ground, root and all, since the local practice of chopping the plant off at ground level resulted in the production of adventitious shoots from the roots and the pest carried on its life on these shoots. This plant-puller has been widely popularized in Gujarat (Bombay Presidency) by propaganda largely financed by the Indian Central Cotton Committee. In the Punjab, however, the cotton plants are bigger and more firmly and deeply rooted, and other methods have had to be devised for that Province.

Pink Bollworm

The work on the Pink Bollworm has been done mostly in the United Provinces and has resulted in the devising of a heat treatment for cotton seeds, now made compulsory by law in the United Provinces. Here again conditions are not identical in all parts of India. While in the United Provinces the pest has almost no resting period in the soil, in Hyderabad State this stage is noticeable and has to be reckoned with.

Cotton White Fly

Much work has been done on the Cotton White Fly (*Bemisia gossypiperda*) which is a serious pest in the Punjab. Its most active period is from May to September, after which it migrates to alternative food plants such as potatoes, turnips and cauliflower. From March to May it attacks cultivated cucurbits and ratoon cotton, whence it spreads to the new cotton crop. Spraying with rosin compound is the most effective control and costs Re.1-8 per acre.

Cotton Stem-weevil

The Cotton Stem-weevil (*Pempheres affinis*) has been studied in Madras, and here again a close period of not less than three months would greatly help to reduce the pest.

The Mexican boll-weevil which is such a serious pest in America does not occur in India. This is largely due to the fact that all imported foreign cotton is fumigated with HCN gas in specially constructed barges at Bombay, the only port through which foreign cotton may enter British India.

(*c*) *Sugarcane Pests.*

Attention to these has become increasingly necessary with the rise of the Indian sugar industry consequent on the protection afforded to it since 1931. The pests of main importance are borers of which the main ones are top-shoot borer (*Scirpophaga nivella*), the stem-borers (*Argyria sticticraspis* and *Diatræa venosata*), and the root-borer (*Emmalocera depressella*). *Pyrilla* species also infest the leaves. The extent of the damage caused by borers was recently estimated by Haldane. As the result of random sampling and analysis (for a group of ten factories in North India) during February, 1937, he estimated that the loss in sugar during a five months season due to borers was Rs.17,50,000. He estimated that the supply of borer-free cane would result in an increase of approximately 1 per cent in the yield of sugar, and a considerable reduction in the production of waste molasses.

Research on these pests on an India-wide scale is being financed by the Central Government and the Imperial Council of Agricultural Research and special attention is now being given to the possibilities of biological control. Already success in using this method is claimed by the Mysore State, where the mass breeding and release of the parasite *Trichogramma minutum*, combined with improved cultural methods has been in progress for some years.

(*d*) *Pests of Fruit Trees.*

These are important particularly in the case of the valuable plantations of deciduous fruit trees grown in North India and Kashmir. For the Punjab and North-West Frontier Province there is now in existence a combined scheme of investigation (financed by the Imperial Council of Agricultural Research) of the dreaded San José Scale (*Comstockaspis perniciosa* Macgilivray). In the North-West Frontier Province the chief objects of the scheme are :—

(1) a survey of the insect pests of fruit trees with special reference to the San José Scale and its host plants ; and

(2) the examination and fumigation of live plants entering India at Peshawar and the Kurrum Valley.

In the Punjab, the scheme is designed to investigate (1) the food plants of San José Scale in the Punjab ; (2) the present distribution of the pest ; (3) the movement of infested fruit or nursery stock ; and (4) the reasons why the pest thrives in certain areas and not in others.

Woolly aphis (*Eriosoma lanigerum* Hausm.) and the apple root-borer are getting attention at Chaubattia (the United Provinces hill fruit experiment station financed by the Imperial Council of Agricultural Research) and certain of the East Malling stocks and

some local selections are showing resistance to the first-named pest.

Mango hoppers (*Idiocerus clypealis*) have been thoroughly investigated in Bombay, with the result that a treatment devised to deal simultaneously both with these hoppers and mildew has been devised. This consists in blowing sulphur powder on to the inflorescences by dust-guns. In Mysore the pest has been kept under control by spraying with Hongey (*Pongamia glabra*) oil soap.

Insect pests of citrus are also important. One of the most curious of these is *Ophideres* of which the actual moth flying by night punctures the nearly ripe fruit with its saw-edged proboscis and sucks out a little juice. The effect of this tiny wound, however, is that the fruit falls to the ground next day and is a total loss. There is also a strange caterpillar the colour of which is a mimicry of a bird's excrement, and another caterpillar with a pair of false eyespots that make it look like a miniature dragon. Thrips and aphis are also under study, the latter specially as possible vectors of virus diseases of plants. Grasshoppers are a serious menace to many crops. Some of these pests are :—

The Rice Grasshopper (*Hieroglyphus banian* Fabr.)
The Deccan Wingless Grasshopper (*Colemaria sphenarioides* Bol.)

Colemania is named after Coleman, who was Director of Agriculture in Mysore State for many years and who discovered and described this insect.

Remedial measures against grasshoppers are various and include drawing open-mouthed cloth bags or tarred iron sheets over the young crop to disturb and then catch the rising grasshoppers.

In Baluchistan and Sind recently a plague of the black-headed cricket has required attention. Indian Entomologists often get grasshopper specimens sent them as locusts, for many of the grasshoppers are large and, to the untrained eye, indistinguishable from locusts.

For all sorts of insects, insecticides of various kinds have been tried. The most generally successful against sucking insects has been fish-oil-resin soap. Nicotine preparations are effective though expensive but recently in Bombay, V. G. Deshpande has made a good cheap insecticide from a cold water decoction of tobacco waste. Tobacco waste from the Belgaum District of the Bombay Presidency was found to be peculiarly rich in nicotine. Pyrethrum has been grown experimentally in Kashmir and the Punjab and is now being tried on a wide range of stations. For several years research has been going on at the Forest Research Institute at Dehra Dun and more recently at Mysore on the insecticidal value of certain indigenous plants that have for centuries been used as fish poisons especially some species of *Tephrosia* and *Mundulea*.

V. Agricultural Chemistry.[1]

The application of science to agriculture started with chemists in Germany and Britain and it was natural that in India too the same should happen. Voelcker, already mentioned in the introduction, was a chemist and Leather, the first Imperial Agricultural Chemist at Pusa laid the foundations of soil science in India. Agricultural Chemistry, so far as India is concerned, might indeed be divided up in Soil Science and the Rest with the accent on Soil Science. From 1904 till 1915, Leather worked on soil moisture, soil temperature and soil gases. According to Leather's work, the diffusion of gases through the soils with which he worked, at a depth of 12″ to 15″ was so efficient that cultivation of surface soils is unnecessary for æration, and the value of good cultivation must be referred to some other causes. Soil Physics and Soil Chemistry have been to a great extent linked in much of the Indian work, particularly in later work on soil classification, effects of organic manures, dry-farming investigations, and reclamation work.

(a) *Reclamation of Alkali Soils.*

This subject has been under investigation during the whole of the twenty-five years. In 1909 H. H. Mann who had then just left the post of first scientific officer to the Indian Tea Association to become the first Principal of the Poona College of Agriculture, and Agricultural Chemist to the Bombay Government, undertook, in collaboration with Tamhane, a study of lands in Nira Valley of the Bombay-Deccan, rendered alkaline and infertile through the application of heavy irrigation to deep black soil with insufficient drainage. This work was carried on later by the Irrigation authorities. Alkali lands due to other causes exist copiously in the Punjab, Sind and United Provinces, and in all these provinces the local agricultural chemists have made their contribution to the work of devising reclamation measures.

(b) *Soil Acidity and Hydrogen-ion Concentration.*

Meggitt (1914 and 1923) worked on the acid soils of Assam and found that the high acidity was due to colloidal substances like hydrated silicic acid, acid silicates, and hydrated aluminium and iron oxides. These soils were also deficient in nitrogen. The soils were found to improve by green manuring and phosphatic fertilizers. Liming gave increased grain and straw of paddy in the acid soils at Dacca.

Atkins (1922) determined the hydrogen-ion concentration of several Indian soils and plants. Charlton (1924) studied the buffer

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[1] In collaboration with Mr. N. V. Kanitkar.

action of Burma soils and showed that the range of fertility of soils may lie between the limits pH 4·5 and pH 9·5. Harrison found the antimony electrode a robust and reliable form of electrode for the determination of pH values.

(c) *Base-exchange and Soil Colloids.*

Agricultural Chemists in India have not only kept pace with great advances in Soil Science in regard to various physico-chemical researches but several of them have also made contributions to this advance. Puri and Taylor at the Punjab Irrigation Research Institute, have worked on exchangeable bases and have evolved methods to determine them.

Exchangeable bases were determined in Burma soils by Hissink's method and also by electro-dialysis in 1928 by the Agricultural Chemist. Parameswar Aiyar (1932) at Coimbatore used the titration method for base exchange, while Dalip Singh and Sukh Dayal (1936) at Lyallpur, have also conducted base-exchange studies on the Punjab soils in connection with reclamation of alkali lands.

The work at Pusa (1928) led the Physical Chemist to formulate the theory that the soil particles could be considered as a colloidal tribasic acid with three replaceable surface-active hydrogen atoms and that the important soil properties depend on the nature and degree of saturation of exchangeable ions. Bacterial activity and plant growth were also influenced by the degree of saturation of the soil colloids.

Mukherjee and others at Calcutta, are engaged in determining some fundamental characters of colloidal material in clay, like silicic acid, humic acid and aluminium hydroxide. These substances behave like strong acids in most respects and as weak acids in some.

Charlton (1932–36) determined various 'single values' of Burma soils and found high correlation to exist between moisture at sticky-point and divalent bases.

Sen and Amin have shown that the absorption of hygroscopic moisture can become useful as a 'single value' for characterizing soils.

(d) *Soil Fertility.*

The question of soil fertility generally has of course received much attention. Starting from the simpler ideas of twenty-five years ago there has been accumulated in every province a body of knowledge as to technique and causes that is having its effect on present-day practice. A typical example is the question of soil nitrogen in Indian soils. On this subject worked Warth (in Burma), Norris and Viswa Nath (in Madras), Hutchinson (at Pusa); Plymen, Annett and Bal (in the Central Provinces) and Sahasrabuddhe (in Bombay). Dhar of the University of Allahabad has also recently been dealing with this subject. The question divides itself naturally

into two sections, namely : (1) the natural recuperation of nitrogen in unmanured soils, and (2) the nitrification of manurial material added to the soils.

As regards (1) it has been found that nitrogen in soils, under tropical and subtropical conditions of temperature and rainfall, does not remain constant. It fluctuates within certain limits in different seasons. Alternate wetting and drying of soils favours natural recuperation. Cultivation, moisture content varying from 20 to 30 per cent, and a temperature of 40° C. favour recuperation of total nitrogen. Nitrate and nitric nitrogen also fluctuate. Fallowing tends to accumulate nitrate nitrogen.

As regards (2), not very much of the cowdung produced in India reaches the soil. Most of it is burnt as fuel in the shape of flat dung pan-cakes dried on a wall or rock. Yet the soils continue to give crops of a sort and yields of a sort. How do they do it ? All the above has of course a direct bearing on the theory and practice of manuring. More than any other branch of agricultural science, manuring has been the subject of field experiments in India with all kinds of crops and all kinds of manures. It is only in recent years, however, that the Fisherian technique has been applied to the lay-out of such experiments and the interpretation of their data. Much of the earlier work done before the introduction of this technique gave indications, but no conclusions significant in the modern sense. However, some of the older experiments could be made to yield to some form of mathematical treatment, and this is exemplified in the book by Sahasrabuddhe ' Experiments in manuring crops in the Bombay Presidency, 1896–1931 '. Vaidyanathan (1936) has collated the results of manurial experiments so far tried in all provinces of India and has applied mathematical treatment so as to make these results more useful.

The most generally used artificial fertilizer throughout the whole of India is sulphate of ammonia. This however can only be used where it pays its way and yields a profit. Hence one finds it used more for sugarcane than for any other crop. In the Bombay Presidency experiments were carried out in 1931–33 to study the movement of ammonium sulphate in typical soils with varying conditions of moisture. It was found that the diffusion of the fertilizer increased with the rising moisture content of the soil, the maximum diffusion being a distance of six inches from the point of application in soils having a moisture content of 50 to 75 per cent of the soil's waterholding capacity. The diffusion was equal in all directions. In the course of diffusion a part of the ammonical nitrogen changed into the nitrate form and in this form diffusion was more rapid. In the chain of sugarcane-research stations subsidized by the Imperial Council of Agricultural Research throughout India one of the problems has already been, how much nitrogen per acre does it pay to apply and in what form. The answers as to amount vary widely from province to province. Sugarcane is

very greedy of nitrogen. At Padegaon in the Bombay Presidency it was found that 300 lbs. nitrogen per acre (as top-dressing) was by no means the top limit and 600 lbs. per acre is now being tried. At that station 50 lbs. per acre (as top-dressing) definitely fell short of the requirements of the sugarcane crop, and existing practice is to give 150 lbs. in addition to farmyard manure. But at Anankapalle in Madras 50 lbs. total nitrogen is regarded as a normal dose (as a result of careful experimentation). In Bihar at Patna 100 lbs. of nitrogen per acre appears to be the best dose, while anything above 60 lbs. nitrogen per acre is reported to be uneconomical in the heavy soils of South Bihar.

As to the form in which the nitrogen should be given, there is throughout India a consensus of opinion that part of it should be given as organic and part as inorganic nitrogen. Sources of organic nitrogen are dung, compost, oilcakes, and green-manuring. There is a fair supply of oilcakes in India obtained from the local oilseed crushing industries handling groundnut, castor, safflower, rape-seed, etc. Castor cake being unfit for cattle food is largely used as a manure. For green manuring India is fortunate in having one outstandingly useful crop,—namely Sann Hemp (*Crotalaria juncea*). 'Dhaincha' (*Sesbania aculeata*) is also used and the standardization of green-manuring in rotations has been the subject of much successful research and propaganda. The use of organic manures and particularly of cowdung, has also the advantages of increasing the waterholding capacity of the soil, of giving better conditions for bacterial activity and (apparently) for enhancing the nutritive value of the food produced by crops so manured.

The utilization of bones has been the subject of a good deal of investigation throughout a number of years. The direct crushing of unprocessed bones has never been very successful. Simple charring, although it causes some loss of nitrogen appears to be a very suitable preliminary to crushing. At Pusa a dilute solution containing a mixture of caustic soda and sodium chloride softened the bones in two months.

Systematic work on phosphatic fertilizers has been limited. Warth (1919) studied the phosphate requirements of some paddy soils in lower Burma. He found that the phosphoric acid deficiency was not general but was restricted to definite areas. The soil nitrogen in such soils was also deficient. Harrison and Das (1921) studied the retention of the soluble phosphates in calcareous and non-calcareous soils. Field experiments with phosphatic manures have shown them to be useful for rice, cane, wheat and cotton, and they are being used in Madras, Burma, the Punjab and Central Provinces.

No account of manure and fertilizer work would be complete without mentioning the work on compost. At Indore, methods have been developed for converting all farm waste material into useful manure. Similar work has been done in Bengal, Bihar,

United Provinces and Bombay. At Bangalore, compost from farm waste and road waste has been made using activated sludge as a starter.

(e) *Soil Microbiology.*

Mann and others (1912) investigated the *Rab* system (burning the seed-bed) of rice cultivation in Western India and found that the partial soil sterilization involved in the method favoured the activity of useful organisms and simultaneously improved the physical and chemical properties of the soil. Hutchinson (1910-11) conducted studies in bacteriological analysis of Indian soils at Pusa. Later on, Walton (1915) studied nitrogen fixation in Indian soils by Azotobacter. Studies on the microbiology of the progressive reclamation of alkaline soils have revealed a close correlation between the bacterial number and the extent of reclamation.

(f) *Soil Surveys.*

While there has never been an all-India Soil Survey, there have been quite a number of soil-surveys dealing with limited areas. In most cases such surveys were undertaken in connection with the solution of definite problems or for finding the suitability of soils for irrigation whenever new irrigation projects were undertaken.

In Madras, extensive tracts of the Godavari, Krishna and Cauveri deltas were surveyed. Surveys of the areas known as the Periayar tract and Malabar were also completed and published. These surveys were done with a view to determining the fertility of the soils of these tracts. The deltaic tracts were found to be well-supplied with the important plant-food ingredients. Soils of the Periyar tract were found to be deficient in phosphoric acid and nitrogen. Soils of North Malabar were well supplied with nitrogen but were deficient in lime and phosphoric acid, while soils of South Malabar were also well supplied with nitrogen and potash but were lacking in lime and phosphoric acid. More recently, extensive areas which are likely to be commanded by four irrigation projects have also been surveyed to find out the suitability of those soils for irrigation. Some alkali patches have been found to exist in these tracts. The soils have been found to be wanting in all plant-foods except potash. Several important physical determinations of these soils have also been made in addition to the fertility constituents.

In Bengal, soil survey was planned by Meggitt in 1914 and was continued between 1918 to 1925 mainly from the chemical point of view. The Indian Tea Association carried out soil survey of tea districts.

In Burma, a soil survey of Pegu and Mandalay District was carried out in 1925-26. It was found that the soils of Pegu division

were highly deficient in phosphoric acid while those of Mandalay were deficient both in phosphoric acid and nitrogen.

In the Punjab, the *kallar* (alkali) problem has been receiving the attention over a long period. Lander and others (1928) have taken a comprehensive survey of all the investigations carried out during twenty years on the Punjab soils. A survey of soils in connection with the extension of lower Chenab canal was completed in 1929, and the survey of Gurdaspur and Amritsar districts was undertaken in 1933.

In Bihar, soil survey of Bhagalpur District was carried out in 1921-22 from the fertility point of view. No particular constituent was found to be deficient. Soil surveys of Suran and Gaya Districts were also undertaken in 1925-26.

In Sind, a soil and subsoil survey of the Lloyd Barrage areas was commenced in 1931 by the Research and Development Division of the Irrigation Department and is still being continued. The survey work includes the determination of the physical composition, salt content, etc., in various strata underlying the surface to a depth of thirty feet.

Soil surveys in connection with irrigation projects have been carried out in Hyderabad and Mysore.

A genetic soil survey of the canal areas in the Bombay Deccan has been undertaken by Basu at Padegaon Sugarcane Research Station.

In 1935, the Geological Survey of India undertook a general survey of soils and a note along with a map has been published describing geological foundations of soils of India, by Wadia, Krishnan and Mukherjee.

Black Cotton Soils

In this connection mention may be made of the black cotton soil investigations by Annett (1910) in the Central Provinces and by Harrison and Shivan (1912) in Madras to determine the factors that contribute to the colour of the black cotton soils. According to Annett, the black colour is mainly due to titaniferous magnetite. Harrison and Shivan did not find the presence of magnetite in all black soils of the Madras Presidency. These were found to have been formed from diverse geological formations. According to them, the black colour and the peculiar physical properties may be due to two classes of substances : one is a colloidal hydrated double silicate of iron and aluminium and the other is organic in character and may possibly be an organic compound of iron and aluminium.

(*g*) *Plant Chemistry.*

Next in importance to the soil and fertilizer work is the work on the chemistry of plant and plant-products.

The nutrition of the rice plant with regard to its periodic intake of nitrogen, potash, phosphoric acid and lime has been studied by

Sahasrabuddhe in Bombay. Dastur (1933) studied in Bombay, the nitrogen nutrition of rice. Harrison and Aiyer's extensive studies on the gases of swamp rice soils have thrown light on the oxygen supply to the roots of rice plants under swampy conditions.

The chemistry of the leaves of the betel vine and their commercial bleaching were studied by Mann, Sahasrabuddhe and Patwardhan (1913). It was shown that the value of the leaf depends upon the potassium nitrate and the essential oil it contains.

The acid secreted by the gram plant was investigated by Sahasrabuddhe. It was found to be malic acid. The plant can secrete the acid again and again if the quantity present is washed off with water.

The chemistry of the germinating seed of safflower was studied by Tamhane in 1921–1923, while the oil-formation in nigerseed was studied by Sahasrabuddhe and Kale in 1933. Patel and Sheshadri studied the oil formation in groundnut in 1935.

Annett working at Cawnpore, made exhaustive studies in the chemistry of opium, the nature of the alkaloids present and the influence of environment.

Another product of industrial importance investigated by Annett was the sugar obtained from date-palm in Bengal. Vishwanath (1919) studied the chemistry of the sugarcane at Coimbatore. Lander (1936) studied the effect of mineral matter in sugarcane-juice on the yield of white sugar.

Amongst other items of investigation in plant chemistry may be mentioned the studies in hydrocyanic acid in the Burma bean, fractional liquefaction of starches (Burma) biochemical study of starch from old and new rice grains (Bombay), studies in the prussic acid content of sorghum, malting properties of sorghum, and hydrolysis of sorghum-starch conducted in Madras.

VI. Agricultural Engineering.

Twenty-five years ago agricultural engineering was just beginning to receive attention. Only two provinces, Madras and Bombay, had employed Agricultural Engineers. The work then consisted mainly in the boring of wells, the substitution of power pumping for water-lifting by bullocks and the introduction of supposedly labour-saving implements and machines. Musto, then Agricultural Engineer in Bombay, got certain manufacturers to re-design all their standard sizes of pumps with a view to obtaining a higher efficiency within the limits in which they were generally worked for irrigation pumping. He also invented a new type of boring plant to be worked by hand labour or bullock gear and which proved successful in hard rock. In 1912-13 Musto was succeeded by Schutte who developed boring and pumping work to a great extent and who devoted much time to the invention of an improved seed-drill. This work was carried on by Paranjpe in

recent years. An improved seed-drill and various other implements have also been designed by Charley in Madras.

Later, agricultural engineering has had a recognized place and many of the provinces employ a full-time Agricultural Engineer as one of their regular staff. In 1921-22, for example, the Punjab, Madras, Burma, Bihar and Orissa, the Central Provinces and Bombay all had agricultural engineers. Not all these provinces have now got agricultural engineers but the work of agricultural engineering is still an important part of the provincial programmes everywhere.

Agricultural engineering is a title which covers a very considerable range of subjects and in India these are mainly: (1) well-boring, (2) apparatus connected with raising water, (3) other agricultural machinery, excluding tractors, (4) tractors and tractor implements, (5) the improvement of bullock-drawn and hand implements, and (6) land improvement and development. Of research in the limited sense of the term, there has not been a very great deal, but there has been an amazing amount of invention applied particularly to *gur*-boiling furnaces, cane-crushing plants for bullock-power or small internal combustion engines, improved water-lifts, e.g. improved Persian wheels, chain lifts, etc., and improved tillage implements. The last named group has been peculiarly prolific and there is hardly a province in which there is not widely used some improved plough, inter-culturing implement or seed-drill. The following are some examples :—

In 1922-23 the Mysore Agricultural Department put on the market a new steel bar suited to the ordinary cattle plough, while a cheap and improved type of iron plough suitable for local conditions was manufactured in the workshop attached to the Agricultural School at Travancore. The Meston plough (called after Lord Meston) remains one of India's standard light ploughs. In 1924-25 the Agricultural Engineer in the Central Provinces invented a reversible blade hoe and a grubber for clearing land of sorghum and cotton stalks. Clod-crushers have been designed in several provinces where the soil demands them. In Bombay and also in Burma paddy-transplanting machines were designed and in Burma, Bombay and Madras groundnut-raising implements for bullock power. At Indore in 1926-27, a yoke was designed long enough to allow of four bullocks walking abreast so that the animals could co-operate equally and exert their maximum power. In 1928-29 in Madras an improved *guntaka* or blade-harrow was standardized and manufactured in three sizes. In North Bihar, the Bihar plough, cultivator and ridging plough designed by Cliff proved very suitable and manufacture and sale were taken up by local firms. Winnowers have been designed in several provinces varying from a power-driven fan in the Punjab to a cheap hand-driven fan with bicycle gear in Bombay. Paranjpe in Bombay has developed a bullock-drawn dry farming implement termed a

Scooper, with four shovels worked by cams off an axle. This makes pockets in the soil which are very effective in holding water and preventing run-off.

Small hand implements, hoes, weeding-hooks and ' cultivators ' have also come in for a fair share of inventive attention. Certain implements have been found peculiarly suitable for certain provinces, e.g., in the Punjab, chaff-cutters have been a tremendous success and are very widely made, sold and used. In the medium black soil area of the Central-Deccan in Bombay the iron plough has largely replaced the wooden plough. A recently devised and very cheap implement is the cotton plant-puller (like a magnified nail-puller) which was devised to take cotton plants out of the ground *with their roots* in order that there might be no roots left to give adventitious shoots on which the Spotted Boll-worm could grow. There is still a considerable scope for improvement in this line of work.

Parallel to this has gone on the mass production by one or two firms of iron ploughs and tillage implements embodying Western principles adapted to Indian conditions and at prices suited to the Indian farmer. The turnwrest plough (a plough with a reversible mouldboard) is very popular in many areas. Two well-known implement manufacturing firms are Messrs. Kirloskar Brothers of Kirloskar Wadi, in the Aundh State (near Satara District, Bombay Presidency) and the Cooper Engineering Works, Satara, Bombay Presidency.

Along with the designing of bullock-drawn implements has gone a certain amount of investigation into the draught of these implements. This has been mostly done by the comparatively crude method of the spring dynamometer but it is hoped in the near future to make more accurate tests with improved dynamometers such as have been recently used in similar researches in England.

The side of the work which has been called land improvement and development is of the greatest importance particularly as a means for the retention of water on the land and for the prevention of erosion. In certain provinces and notably in Bombay special officers have been set apart to deal with applications for land improvement who survey the land, make estimates and see the work carried through. In this way systems of embankments of various sizes, shapes and designs fitted with suitable waste-weirs have been constructed in several parts of the Bombay Presidency. This represents the first line of defence against erosion but along with this has also gone the making of small embankments of 2″ to 6″ in height as part of the dry farming system also developed in Bombay and now under study and modification in Bombay, Madras, the Hyderabad State and the Punjab.

Mechanical ploughing started about 1912-13 with double-engine steam ploughing (Fowler's plant) and the Bajac windlass plough. Later on, experiments in mechanical cultivation by means

of tractors and tractor ploughs were largely financed by the Burmah-Shell Company for a series of years and the results are published in Scientific Monograph No. 9 of the Imperial Council of Agricultural Research entitled 'Mechanical Cultivation of India—a history of large scale experiments carried out by Burmah-Shell Oil Storage and Distributing Company Limited'. This monograph gives full details of the work done, the results obtained and the costs. Generally speaking, tractor ploughing in India is for the present likely to be limited to (1) individuals and companies owning or working large tracts of land, such as certain sugar companies, and (2) contractors undertaking to do the eradication of deep-rooted weeds for so much per acre.

In the heavy black soils of the Deccan, it has not been easy to get tractor implements that would stand up to the strain of deep ploughing but it is believed that such have now been discovered. In addition, there have also been worked in India various models of the Gyrotiller (Fowler) which pulverizes the land by two heavily toothed gyros attached to the tractor itself and behind which can be pulled furrowing or ridging implements.

Well-boring has been of different types according to the nature of the substratum. In the United Provinces, tube-wells are now a well-recognized part of the agricultural system and are part of the hydro-electric development introduced by Stampe. Miller-Brownlie, recently Agricultural Engineer in the Punjab, received the Maynard-Gangaram prize of Rs.3,000 for his invention of a slip strainer suitable for water augmentation supplies derived from bores sunk in open wells. This strainer has the particular merit of not being affected by alkaline sub-soil water, a defect from which many of the earlier strainers suffer. Miller-Brownlie had invented a new type of tube-well as early as 1912-13. In the Bombay-Deccan on the trap area where water runs largely in fissures considerable use has been made of the Mansfield Water-Finding machine with considerable success. Human water finders—British and Indian—have also been employed with a fair amount of success.

Agricultural Engineers have thus a great deal of work to their credit in a comparatively short period of time. The subject of Agricultural Engineering, however, certainly needs more attention, more systematization, and a closer linkage with soil physics in research on soil-working implements.

VII. Plant Physiology and Biochemistry.

While, from the beginning, plant physiology has always been part of the background of workers in plant genetics, soil chemistry, plant pathology and entomology, its emergence as a separately recognized subject really dates from the establishment of the Imperial Council of Agricultural Research. It first appears as a separate heading in the *Review of Agricultural Operations in India* for the year

1929-30. The earlier work of a physiological character was to some extent largely observational, dealing with the effects on the plant of certain soil treatments or conditions in the field. . In the Punjab, Trought, then Cotton Research Botanist, published in 1929-30 two papers (one in collaboration with Mohammad Afzal) on the physiological response of the cotton plant to its environment, this being an attempt to determine the factors responsible for the so-called 'failure' of the cotton crop in the Punjab in various years. Previously D. Milne had given considerable attention to this same malady and attempted to connect it up with humidity and temperature. According to Trought and Afzal, the experimental evidence showed that in some years the effect of certain climatic conditions, or the accumulated effect of a succession of unfavourable conditions, is sufficiently severe to produce a general pathological state in the plant. The symptoms of this condition are the premature opening of bolls, the non-development or shrivelling of the embryo and the non-production of satisfactory lint. The root development of the plant, according to Trought and Afzal, exercises a preponderating influence on the good or bad nutrition of the bolls. The major climatic factors are: excessive heat and drought in the early part of the season, an abnormal number of dust storms, puddling or water-logging of the soil, producing as a final result a competition between bolls and complicated by white fly attacks. These periodic failures of American cotton in the Punjab were made the subject of a new physiological research financed by Indian Central Cotton Committee. This started in March, 1935, and was put under the charge of R. H. Dastur of the Royal Institute of Science, Bombay, who accepted the direction of this research, temporarily relinquishing his professorship. The work so far done appears to show that in plants suffering from the disease there is a breakdown of the chlorophyll apparatus, associated with accumulations of starch in the leaves, and of certain tannin-like deposits in the phloem of the root and stem. The accumulation of an excess of organic acids within the plants is another phenomenon associated with the disease. Certain bacteria were found in all parts of the diseased cotton plants, with the exception of the embryo, but it has not been found possible either effectively to sterilize the seeds or to reproduce the disease by inoculating these bacteria into healthy plants.

Sind is a province with extreme climatic conditions and from 1927 to 1936 the Indian Central Cotton Committee financed in that province a physiological research scheme dealing with cotton. In 1932 it was definitely concluded that from March 15 to May 15 was the optimum period for sowing cotton under irrigated conditions in Sind. Work done on the water requirements of cotton over the whole period of the research showed that these requirements are highest during the flowering and fruiting periods, and that an initial watering of 8 inches during the first period of 28 days followed

by two irrigations of 3 inches each at 10 days' interval gives the highest yield. As regards manures it was shown that satisfactory returns can be expected when compost alone is given at the rate of 15 cartloads per acre before sowing or at the rate of 7½ cartloads per acre before sowing followed by 50 to 100 lbs. ammonium sulphate per acre 1½ to 3½ months later.

An important and definitely physiological investigation was carried out at Surat by K. V. Joshi and his colleagues from 1923 to 1933 on the physiology of the shedding of buds and flowers and bolls of the cotton plant, the results indicating that shedding is a natural phenomenon and mainly due to competition between the developing bolls and the co-existing buds, flowers and young bolls. Degree of shedding was also found to be, in some degree, hereditary. The same phenomenon had also been investigated in Madras by Hilson and his colleagues who published the results in Pusa Bulletin No. 156 of 1924-25. The same problem is still under investigation in the Punjab.

In 1915, Parnell published a paper on the physiology of indigo-yielding glucosides based on work carried out at the Indigo Research Station, Sirsiah, Bihar, and in 1920 Youngman published a paper on the influence of atmospheric conditions on the germination of Indian barley. The Indian Tea Association carried out some work on the distribution of tannin within the tissues of the tea plant and a separate branch to study the physiology of tea was opened at Tocklai about 1929.

At Karjat in the Bombay Presidency, K. V. Joshi and others carried out work from 1919 to 1934 on the nutrition of the rice plant, the object being to determine the factors involved in producing a maximum crop.

J. N. Sen in 1915-16 published in Pusa Bulletin No. 65 the results of 'A study in the assimilation of nutrients by the rice plant'. Dastur (already mentioned in connection with the 'cotton failure' research) was in charge of a research on the physiology of rice plant financed by the Imperial Council of Agricultural Research between 1932 and 1935. In 1931 Dastur studied the osmotic and suction pressures of the roots and leaves, the photo-synthetic activities of the leaves, the intake of nitrogen and the relative growth rate of plants. In the 1932–35 research, which had as one of its objects, the special study of the intake of nitrogen, it was found that from a solution of ammonium sulphate, the rice plant absorbed a greater quantity of NH_4 ions than of SO_4 ions. This was found to be true in all stages of growth. The absorption of NH_4 ion decreased as the plant aged while the absorption of nitrate ion increased as the plant aged. Based on this, the conclusion was drawn that a mixture of ammonium salts and nitrate is a better fertilizer than either alone. This was tested out by properly randomised large scale experiments on a considerable number of research stations throughout India in the year 1935-36 and the

results of these experiments were that only in one place, viz., in Travancore on light laterite soil did the mixture of manures give the heaviest yields. In all the other places either sulphate of ammonia gave the best yield or there was no significant difference between sulphate of ammonia and the mixture of sulphate of ammonia and nitrate of soda.

The physiology of the rice plant has certainly something very peculiar about it and we are very far from understanding it fully. The early work (1920) of Harrison and his colleagues on the gases of the rice soils indicated that the algal film which covers the surface of swamp paddy soils, and which evolves large quantities of oxygen, is the chief agent in causing the æration of the roots of the crop. Pran Kumar De has also been working on this problem, but thinks the fixation is an algal process, though it is not yet possible to decide whether this fixation is due to the algæ alone or in symbiosis with other organisms. The more recent work of Sahasrabuddhe, which he has confirmed in various conditions of rice cultivation at different places in the Bombay Presidency, shows that there is a definite fixation of atmospheric nitrogen in the soil of rice fields and that this fixation is helped by the presence of the growing roots of the rice plant. It has been shown that the rice seed does not carry within it any nitrogen fixing organisms.

Water requirements of crops, a subject which may certainly be regarded as physiology, has been attacked from all angles by different workers from the time of Leather, the first Imperial Agricultural Chemist, work which he commenced in 1907 and continued till he left India in 1915. His first results were published in 1909-10 as Pusa Memoirs, Chemical Series, No. 8. The effects of temperature and humidity, proportion of water in the soil, manure and the nature of the crop were dealt with. It was shown that manure, whilst increasing the weight of the crop and consequently the amount of water required, effected an economy of water, since the crop increase is proportionately greater than the water increase. In 1910-11, in a second Memoir, No. 10, Leather showed that the nature of the soil had no effect on the transpiration ratio, but that this factor had a great influence on the rate of water movement, hence indirectly on the weight of crop produced. He also stated that field experiments over several years (at Pusa) showed that practically the whole of the water assimilated by the crop was obtained within the root-range, some 6 to 7 feet in alluvial soil, and that stores of water below this depth were substantially of no service to the plant. This opinion was later modified by experiments at Cawnpore where the soil moisture was drawn upon to a greater depth. This study of water requirements is now being carried out both by pot experiments and field experiments with careful measurements of the water applied and lost at several of the sugarcane experiment stations and the dry-farming research stations.

At this point plant physiology and agricultural meteorology come into contact, and it is necessary to say a word or two about the latter subject. In 1930, the Imperial Council of Agricultural Research, following up the recommendations of the Royal Commission on Agriculture approved a scheme for the establishment of a section of agricultural meteorology at the Indian Meteorological Department headquarters at Poona. This scheme was started from August, 1932, was extended up to August, 1937 and again for another year, and it is hoped that it may become a permanent part of the Meteorological Department. The work done in this branch has been of a very varied character. There has been much designing of new instruments and great attention has been given to the study of micro-climates (i.e., the climatic conditions near ground and amongst crops in particular localities). Studies have also been made of the exchange of moisture between soil and air layers and above it which have shown that water lost to the atmosphere during the day in certain conditions is more or less regained by absorption from the atmosphere at night. It has also been shown that the diurnal variation in the moisture content of the soil surface is maximum in the black cotton soils, moderate in the red lateritic soils and minimum in the alluvium soils. Arrangements have been made for giving telegraphic warnings to local governments of the approach of frost and an attempt has been made to correlate crop yields with climatic conditions.

An interesting example of the subsidizing of pure research by the Imperial Council of Agricultural Research is the grant made to Bosi Sen to help on his unique research work into the properties of living protoplasm. This work, which involves an exceedingly delicate and specialized technique for the study of the individual plant cell, is intended to investigate the effects of different cations and anions on living protoplasm. Bosi Sen has found that the protoplasmic particles of the root-hair of *Azolla* (the cell with which he is mainly working) are negatively charged. He has invented an 'Increased Permeability' technique whereby, after an electric stimulus, the plasma membrane of a cell is more permeable to ions in a surrounding solution. The introduction of Na, K, Mg, Ba, Sr and Ca ions by this method and also by micrurgial technique produce granules of different types and behaviour in the living protoplasm. The following admirably cautious statement by Bosi Sen himself summarizes the position :—

'In interpreting the results of observations on living protoplasm, it is well to remember that we do not know what the particles of protoplasm actually are ; neither do we possess any definite knowledge of the composition of the dispersion medium of protoplasm. Remembering that one is dealing with entities less than a μ in size and with very thin films, one has to be on guard that one is not observing a series of consistent errors. Realizing all

these points, one can do no more than list the observed facts and wait for further data before coming to any definite conclusion.'

From the point of view of biochemistry rather than plant physiology, there may be mentioned the study of the malting of sorghum. This study had been carried out for some time by the Agricultural Chemist in Madras and the work was financed as a three-year programme from 1935. The previous work had shown that malted sorghum compared favourably with various malted foods already on the market and the scheme now in progress aims at evolving a technique which will give a standard product of good quality. Biochemical work is needed on optimum temperature conditions, control of enzymes, and a study of the changes in carbohydrates, fats and proteins. The fat content of sorghum is one of the factors which lower the keeping quality of the malted meal.

The malting and brewing qualities of improved barleys are also being investigated in the Punjab, United Provinces, Bihar and Orissa. A test is being carried out at the Institute of Brewing in London. Certain types have been found that are fairly satisfactory for brewing and others more suitable for distilling. The vitamin content of mangoes was the subject of a small research carried out in England where, as regards vitamin C, the Alphonso mango was shown to be one of the most potent sources known.

Plant physiology has always been a strong subject at the Benares Hindu University and a research on the physiology of sugarcane and wheat has just been started there.

VIII. The Application of Statistics to Agricultural Experiments.

Perhaps in no branch of agricultural science has the effect of pure science been more marked than in the lay-out and interpretation of field experiments. The days when the comparison of two treatments or two crops was made by sowing an acre of one alongside the acre of the other are now very far behind us. As far back as 1911, A. C. Dobbs wrote a preliminary note on the technique of field experiments at Sabour. In 1917 Parnell wrote an article on the probable error of field experiments in the case of varietal trials with rice and in 1923 B. N. Sarkar wrote a similar article on the probable error in variety trials with paddy at Bombay. In 1928 Iliffe and Viswa Nath (the present Director of the Imperial Agricultural Research Institute, New Delhi) published a Bulletin (No. 28 of the Madras Agricultural Department) on 'The Conduct of Field Experiments' a useful discussion of certain principles and practices, and taking the reader up to the use of 'Student's' method in the field. About 1923–24 Burns, then Economic Botanist to the Government of Bombay, drew the attention of Mahalanobis to the subject of interpretation of field experiments, resulting in the

latter's first article on 'The Probable Error in Field Experiments in Agriculture' (*Agr. Jl. Ind.*, **16**, pp. 60–68, 1924). This small event was the germ of the vigorous and unique Statistical Laboratory under Mahalanobis at the Presidency College, Calcutta—a laboratory which is India's School of this subject and which in addition to its admirable research work, also trains annually an increasing number of agricultural and other workers in the theory and practice of modern statistics. As is well known, present day field experimental technique is largely based on the work of Fisher in England, work which, however, on its theoretical side requires a high degree of mathematical training. It is the particular merit of Mahalanobis that he has been able to help less fully trained workers to apply these methods safely to experimental lay-outs and the estimation of significance of experimental results.

The Imperial Council of Agricultural Research in 1930 appointed its own Statistician—M. Vaidyanathan,—who both by consultation and by publication has done a great deal to make known the principles of agricultural statistics and to correct and guide work at the experiment stations. At the Institute of Imperial Agricultural Research at Pusa, the late F. J. F. Shaw used to give a series of lectures on statistics as applied to agriculture and shortly before he died, he completed a publication 'A Handbook of Statistics for use in Plant Breeding and Agricultural Problems' which is a useful handbook for all concerned with field experiments in India. Its main value lies in the fact that all its examples, most of which are fully worked out, have been taken from actual experiments carried out mostly at Pusa.

In more recent years special problems have arisen in connection with sampling methods to be used in estimating the relative virulence of attacks of insect pests on plots under different treatments and, in applying to Indian conditions, lay-out methods devised in England for work on fruit trees. Sampling problems have been always with us. In 1913–14 Leather published a Memoir (Chemical Series III, 4) on 'Experimental Error in Sampling Sugarcane'. In the same year he published another memoir (Chemical Series III, 6) entitled 'The Yield and Composition of the Milk of the Montgomery Herd at Pusa and Errors in Milk Tests'. In 1926–27 J. A. Hubback, I.C.S., published as Pusa Agricultural Research Institute Bulletin 166 'Sampling for Rice Yield in Bihar and Orissa'.

This question of crop yield estimates continues to be very pressing and sampling methods to be applied to crop cutting experiments are being further studied by Mahalanobis, Vaidyanathan and others. It has been proved that present estimates of the area under jute are in certain districts at least, very erroneous and the Indian Central Jute Committee is now financing an exploratory scheme to devise a scientific method, based on the principles of random sampling, for the more accurate estimate of the jute area, and to determine the limits of error of such an estimate.

Agricultural statistics is indeed a very live subject at present in India.

IX. Fodder Production.

Fodder production in India falls into two well marked divisions :—

(1) Grass production, and
(2) The production of crops grown for fodder.

This rough division, however, requires two modifications :— (a) there are certain introduced grasses (e.g., Guinea grass) which are really treated as crops, and (b) the main fodder over the greater part of India is *Kadbi* which consists of the dried stalks of sorghum after the heads have been removed for grain.

Grass Production

Grass production in India has received a certain amount of attention but this attention has been somewhat sporadic. Over the greater part of India where the rainy season lasts for six months and the dry weather for six months, conditions are far from ideal for grassland. The type of grassland existing in these areas consists largely of perennial grasses growing in tussocks of which only the under-ground parts remain alive during the dry weather. In addition, there are a certain number of annual grasses which seed in October-November and spring up again when the rains break in June or July. In parts of India favoured with both monsoons, the grass lasts correspondingly longer, while in desert areas the grasses are of a highly xerophytic character and very sparse.

The botanists of India have always paid a good deal of attention to grasses, not only describing them but also referring to their uses. Roxburgh in his *Flora Indica* (1832) often gives rather full notes on the uses of certain species. One of the early books on grasses is 'Fodder Grasses of Northern India' by J. F. Duthie (1888), Director of the Botanical Survey of Northern India. He had very sound ideas on grassland treatment and was one of the first to recommend ensilage. J. C. Lisboa in 1896 published his 'List of Bombay Grasses and their Uses' with notes on their habitats and feeding values. Williams and Meagher in 1932 published their 'Farm Manual' which contains a whole system of practical grass farming of an intensive nature. In 1921 Rangacharya published his 'Handbook of South Indian Grasses'. About the same time R. S. Hole, Forest Botanist produced a monograph entitled 'Some Indian Grasses and their Ecology'. Mahta and Dave in the Central Provinces published some excellent work on grassland improvement. Blatter and McCann's large monograph 'The Bombay Grasses' was published in 1935 by the Imperial Council of Agricultural Research. The Forest Department have devoted a very great deal of attention to grassland improvement and 'The Indian Forester' contains a large number of useful

articles on this subject. A systematic attempt to apply principles of range improvement, already found useful in America, was made by Burns, Kulkarni and Godbole in Bombay and the results are contained in the *Memoirs of the Department of Agriculture in India*, Botanical Series, Vol. XIV, 1925, and Vol. XVI, 1929. This work showed clearly that even with comparatively poor lands and an annual rainfall of not more than 25", a great improvement could be effected by rotational grazing with a properly controlled number of cattle.

The whole question of grassland improvement has recently come very much to the front and was discussed at considerable length at the Animal Husbandry Wing of the Board of Agriculture which met in Madras in December, 1936 and at the Cattle Conference which met in Simla in May, 1937. One of the important recommendations of these conferences was the formation of a Standing Fodder and Grazing Committee at the Centre, i.e., as one of the committees of the Imperial Council of Agricultural Research and the formation of similar committees in the provinces. The work of these bodies, which will be fully representative of all interests involved, will be to plan, to co-ordinate and to carry out the improvement of fodder and grazing in all suitable areas.

Of introduced grasses grown practically as crops, the important ones are Guinea grass (*Panicum maximum*) and Rhodes grass (*Chloris gayana*), while experiments have been made with Elephant grass (*Pennisetum purpureum*), Sudan grass (*Andropogon halepense*), Para grass (*Panicum muticum*), Teff grass (*Eragrostis abyssinica*) and others. Where irrigation and manure are available or where the washings of byres can be utilized, these grasses give an excellent return and green fodder throughout the year. It is proposed to experiment with certain other exotic grasses likely to be of use including some of the African *Digitarias*. There has not been much experimentation on the effect of fertilizers on grassland but the Imperial Council of Agricultural Research has recently sanctioned a five-year scheme for the study of the effect of phosphatic manuring on grassland at Hissar in an area of low rainfall in the Punjab. There has been no attempt at the scientific selection of the natural grasses. This is an absolutely untouched section of plant-breeding work in India.

Fodder Crops

As regards fodder crops, mention has already been made of the use of *Kadbi* (viz., the dried stalks of grain varieties of *juar*) (sorghum) but there are also certain types of *juar* which are grown specially for fodder. These, as a rule, have thinner stalks and less grain than the grain *juars* proper and almost every *juar* tract has got one or more of these fodder varieties. Maize is also grown for fodder (as well as grain) among the leguminous plants. The most important is *berseem* (*Trifolium alexandrinum*) which grows well in Northern India, i.e., N.W.F. Province, Sind, Punjab, United Provinces and Bihar, under irriga-

tion. The introduction of this crop has brought about a great improvement in the general system of farming since it not only gives an admirable fodder but also definitely improves the ground and makes a considerable difference to the succeeding crop. Its seed production, however, is still rather uncertain and requires more scientific attention. *Berseem* has also the great advantage that it thrives on land considerably affected by alkali.

The sun-flower is also proving a very useful plant for giving a large amount of green fodder quickly at almost any time of the year.

In the Central Provinces, a species of bamboo (*Dendrocalamus strictus*) is grown for fodder purposes and, until the prickly pear (*Opuntia elatior*) was wiped out in the Bombay-Deccan by the cochineal insect (*Dactylopius tomentosus*), that plant could be used for cattle food during periods of famine by burning off the spines with gasoline torch and mixing the singed and chopped material with cotton hulls or similar rough material. There is a considerable range of trees which are useful for fodder and one or two weeds, e.g., *Pluchea lanceolata.* The tops of the sugarcane and in some case the whole cane are also fed to cattle.

In one or two provinces there are special scientific officers for the study of these crops such as the Millet Specialist at Coimbatore and the Fodder Specialist in the Punjab. Normally, however, the scientific work on these crops is part of the duties either of the Economic Botanist, the Professor of Agriculture or one of the Deputy Directors.

The most pressing need at present is crop planning whereby a greater area may be put under intensive fodder cultivation. To release this area for fodder, it is necessary to grow the more high-yielding grain and cash crops now available in the provinces as the results of the plant-breeding work of the last twenty-five years. This will be one of the main objectives of the Fodder and Grazing Committees in the near future.

X. Fruit Culture.

In the early days of the Agricultural Departments in India fruit culture was nobody's child and, in fact, was regarded with tolerance as a not too useful sideline. There was *so much* to be done with *the staple crops*! At the Board of Agriculture held in Pusa in 1910, Robertson Brown, then Agricultural Officer in the North-West Frontier Province and always a keen horticulturist, introduced the subject of fruit culture, 'As one' he said, 'who somewhat doubtfully throws his hat into the ring.' The same Robertson Brown in the North-West Frontier Province, the Howards in Pusa and Quetta, Burns in Poona and Graham in the Central Provinces started work on the fruits of their respective areas. The Quetta Station was opened in 1911 and during the Howards'

régime did much useful work. After their departure from India in 1924 it had ups and downs till 1932 when it was again put on a firm footing with a fully qualified officer (A. M. Mustafa) and an Entomologist and Mycologist. (This work was interrupted by the Quetta Earthquake of 1935 when the station was wrecked, but it has irrepressibly risen from its ashes and is again in full vigour.) Now, very largely due to stimulus and subsidies from the Imperial Council of Agricultural Research practically every fruit of importance is the subject of investigation in some Province or State.

Early work in India was mainly concerned with classification, pruning, propagation methods and certain important diseases. The Howards found that stocks like Black Damask and the Mazzard used on the damp soils of Britain and North France were unsuitable for the hot dry soils of Baluchistan. On the other hand such stocks as the Mariana, Myrobolan, Mahaleb and Jaun de Metz imported from New Orleans did very well. Burns introduced in Poona the espalier method of guava cultivation and also experimented with growing guava trees in pits blasted in rocky land. He also took up the pruning of the citrus and the fig, following the work of Quinn in Australia. The guava work was pursued later by G. S. Cheema who has been able to distribute three varieties of nearly seedless guavas. In Western India the mango received a great deal of attention. Burns and Prayag's bulletin *The Book of the Mango* published by the Bombay Agriculture Department in 1920 has a cosmopolitan reputation. This mango work has been continuously and consistently followed up and the results have been a considerable improvement in grafting methods, a spread of the best varieties and particularly of the Alphonso (also called Alphonse, Apoos and Afoos). The canning of mango juice and mango slices has for years been done by small enterprising firms and also experimentally by the Bombay Agricultural Department. The most recent development has been research work in the cold storage of mangoes. This scheme is financed by the Imperial Council of Agricultural Research and is located at Poona, at the Ganeshkhind Fruit Experiment Station. Now gas storage has also been undertaken, and an officer of the scheme who was sent to England for special training in this line of work has returned to begin it in Poona. The Ganeshkhind Fruit Experiment Station has a long and chequered history being by turns a fodder farm, a drug farm, a botanical garden, and now a fruit experiment station.

The physiology of the mango is receiving a good deal of attention at the Experiment Station at Sabour in Bihar, where the well-known phenomenon of biennial bearing (i.e., a heavy crop alternating with a light crop in successive years) is under study.

A Horticulturist (G. S. Cheema) was recruited for the Bombay Presidency in 1921 and has greatly developed all fruit work in that Province. In the Punjab a Fruit Specialist (Lal Singh) was appointed about 1926 and has similarly brought on fruit work

in that Province. In the United Province a Fruit Specialist was appointed in 1935. The Central Provinces has now a citrus specialist, the first lady graduate in agriculture in India, Miss Rajul Shah, a graduate of the Poona College of Agriculture (Bombay University) and M.Sc. of Michigan University, U.S.A. She is carrying on research work on all aspects of citrus cultivation. Mysore State has always been to the fore in fruit development.

India has one or two excellent types of oranges. Nagpur is the main centre of this cultivation in Central India. The Nagpur 'Santra' is a loose-skinned orange of the mandarin type. The ease with which the skin of the fruit and also the skin of the individual segment can be removed, and the sweet strong-flavoured juice make this a peculiarly attractive fruit. Research is in progress in propagation methods, pruning, manuring, packing and marketing. The tree suffers from a strange physiological disease, one of the 'diebacks'. In some cases it has been cured by drainage. It appears to be associated with unsatisfactory soil conditions. The 'Musumbi' (a corruption of the word Mozambique) is the other well-known orange of Central and Western India. It is paler in colour and not so full-flavoured as the 'Santra' and has less citric acid. The next most important citrus fruit of these areas is the 'Kagadi limbu', a little round lime, the size of a golf ball, very acid, making a good lime-juice, and extraordinarily hardy. Assam has a group of indigenous citrus species, some wild and some cultivated, on the Khasi Hills. These have attracted some attention from foreign scientists.

A beginning in the study of citrus was made in 1931, and a scheme financed by the Imperial Council of Agricultural Research is now dealing with citrus classification, culture, propagation and diseases, at Anakapalle in Madras.

Cheema and Bhat have examined the classification of Indian citrus fruits in their paper. A study of the citrus varieties of the Bombay Presidency (*Current Science*, Feb. 1934, p. 298). Tanaka, who visited India in 1934–35 and made very careful study of all the citrus varieties, has also helped to get a clearer idea of the relationships of the Indian species and varieties. Until these modern attempts practically nothing had been done since Bonavia wrote in 1890.

The making of fruit juices has been the subject of much research work both in Bombay and the Punjab. In the last-named province the methods devised for making fruit juices are now being widely exploited and there has grown up a thriving business in juices and syrups. With jams and jellies India has not been so fortunate, as the demand for these is comparatively small. An experiment station started in Madras for dealing with hill fruits was closed down.

Reverting again to citrus fruits it may be mentioned that the grape-fruit has been in the last few years introduced into India and is doing extraordinarily well. One of the earliest plantations of

grape-fruit is on the Government Farm at Mirpurkhas in Sind and the present writer has never tasted any grape-fruit he liked better. These Mirpurkhas trees are Marsh grape-fruit but the local conditions have given them an additional sweetness. At Poona and Nagpur grape-fruits are doing well and bear in their third year.

The big cousin of the grape-fruit, namely, the pomelo, is widely grown in scattered small plantation and as individual trees. It is very hardy, stands drought and heavy rainfall, is resistant to 'dieback', and produces an enormous fruit of a combined orange and quinine taste, very good when eaten with sugar. This fruit would well repay selection.

In India as elsewhere all the citrus species show much variation and there is a large scope for good work in taking buds only from the best trees. Research and propaganda on these lines are in progress in Bombay and the Central Provinces and certain nurserymen have been converted to these ideas.

The North-West Frontier Province, the Punjab and Baluchistan and of course Kashmir and the northern parts of the United Provinces form the area where the deciduous fruits do well. Apples, pears, peaches, nectarines, quinces, persimmons, peaches and plums flourish there. The work of the Howards and their successors in improving these fruits in Baluchistan has been already mentioned. In the North-West Frontier Province, Robertson Brown did marvels, distributing as many as 30,000 budded or grafted plants per year. The United Provinces experiment station for these fruits is at Chaubattia, near Ranikhet and there work (financed by the Imperial Council of Agricultural Research) is in progress on the apple root borer (*Lophosternus hugelii*), the woolly aphis (*Schizoneura lanigera*), on cultivation, manuring, soil problems, and stocks. The annual show of hill fruits organized each September in Simla by the Punjab Agricultural Department gives a good idea of the range and excellence of these fruits. The main difficulty with these fruits is not so much the growing of them as the marketing of them, and questions of transport and marketing loom large. For example at Kotgarh about 40 miles from Simla excellent fruit is grown but it must be brought to the rail-head at Simla on the backs of mules and, at the fruit-harvest time there is also a great demand for mules to transport the potato crop. There are special fruit vans on most railways, not yet specially cooled, though that is coming in the near future. Cold storage transport, especially by motor lorries, is now a subject of great interest to the army authorities, and most useful collaboration between the army, certain commercial interests and the Agricultural Departments has been arranged by Imperial Council of Agricultural Research.

Grapes grow well in Northern India but by far the greatest amount of grapes that India consumes comes from Afghanistan, being brought by motor lorry to the rail-head at Chaman. Nasik

in the Bombay Presidency is also a grape centre of considerable local importance. Grapes in India are entirely for the table, there is no wine manufacture. Work on grapes in India has been largely a matter of improvement in cultivation methods, including treatment of diseases. Introduction of foreign varieties into Peninsular India has not been very successful. Certain seedlings produced in Poona are promising. In North-Western India there is more scope for the trial of foreign varieties but the existing varieties and especially the little seedless grape, the *Bedana* take a lot of beating. In the Punjab certain crosses between Indian and foreign grapes have been made.

The papaya is a typical tropical fruit and offers a series of perplexing problems which are now being tackled. It is normally diœcious (with male and female trees) but all sorts of intersexes exist, some with most peculiarly shaped fruits. We know nothing of the inheritance of its sex and nothing of the inheritance of good fruit characters. Papaya fruits vary enormously. The best are delicious, the poorest are insipid mush. The cultural problems are being investigated at Sabour (Bihar) and the cytological problems by Kumar at Poona, both activities being financed by Imperial Council of Agricultural Research.

Other fruits now on the research list are pineapples and bananas. India grows fair pineapples and this cultivation could be largely extended. Experimental work on pineapples is being conducted at Kumta and Ratnagiri in Bombay, at Krishnagar in Bengal and elsewhere.

Bananas are widely grown and there is a very great variety of these. Just north of Bombay, along the coast, there are miles of banana gardens. There may be found the delicate little *Sonkel* (golden banana) and the large coarse red banana (*Tambda*). There is also a dwarf type, the *Basrai*, of which the fruit retains its green colour even when ripe. Its hardiness as a tree and its good packing qualities as a fruit have made the cultivation of this type spread in many parts of India. In Madras we have an equal if not a greater range of banana types and at the Coimbatore Research Station the Systematic Botanist has collected, described and classified about 300 varieties. There seems no reason why, in time, some of these really excellent Indian bananas should not find their way into the Liverpool market, provided the necessary sea transport were available.

There are a number of wild or semi-wild fruits in India, some of which have received attention from horticultural workers. The chief of these wild fruits is the *bor* or *ber* (*Zizyphus jujuba*) of which there are many forms of very differing fruit quality. It is comparatively easy to bud *ber*, if the right method is used and a variation of the ring method answers well.

There are also certain fruits little known in the European market that are deservedly popular in India, such are the *Chiku*

(*Achras sapota*) which grows to perfection on the coastal lands of North Gujarat in the Bombay Presidency, the *phalsa* (*Grewia asiatica*) and the *litchi* (*Nephelium litchi*) ; all are delicious.

The manuring of fruit trees has naturally received a good deal of attention. Experiments in the Punjab have shown that bonemeal and sulphate of ammonia in conjunction with farmyard manure give the highest yields. At Samalkota in Madras, it has been found that an application of potash increases the keeping quality of bananas.

All the newer fruit experiments are being laid out on the East Malling model and some East Malling and Meston fruit stocks are showing promise at Chaubattia.

As regards horticultural literature, outside the publications of the Agricultural Departments, the great standby has for years been Firminger's *Manual of Gardening for India.* The book was first issued in 1863. The 6th and 7th editions were thoroughly revised and partly re-written by Burns. Macmillan in Ceylon produced his *Handbook of Tropical Gardening and Planting* in 1914. There has recently been a healthy output of practical horticultural handbooks in various Indian languages.

XI. Agricultural Economics.

There have always been writers on Indian agricultural economics. Some of their works are :—

Moreland's *India at the Death of Akbar ;*

M. L. Darling's *The Punjab Peasant in Prosperity and Debt* (2nd ed., 1928) ;

N. N. Gangulee's *Problems of Rural India* (1928) ;

F. L. Brayne's many writings ;

The studies of the Indian Village Welfare Association (London) ;

Keatinge's *Rural Economy in the Bombay-Deccan* (1912) ;

N. G. Ranga's *Economic Organisation of Indian Villages* (1929) ;

and many others too numerous to mention.

Recently scientific investigations using modern methods of enquiry have been carried out in Bombay where a fully trained Professor of Agricultural Economics has been one of the staff of the Poona College of Agriculture since 1925. In the Punjab a body termed 'The Board of Economic Enquiry' has financed and guided a great number of investigations of village economics. Bengal also has a Board of Economic Enquiry. Various independent organizations have also undertaken this work such as Tagore's Vishwa Bharati Institute of Rural Reconstruction at Shantiniketan and the Gokhale Institute of Politics and Economics at Poona. The latter Institute has received a small grant from the Imperial Council of Agricultural Research for the application of the survey method,

mainly as a study of methodology, to certain agricultural problems in the Bombay Presidency. The Professor of Agricultural Economics in Bombay and his colleagues have devoted themselves very largely to cost studies in peasant farming and one of the publications produced by them in recent years is *Principles and Practice of Farm costing with Farm Studies* (1932) by P. C. Patil and T. B. Pawar. As an example of the kind of work done in the Punjab, there may be mentioned the following :—

Farm Accounts in the Punjab (1932) by Kartar Singh ;
Punjab Village Surveys, No. 4 (1932) by Randhir Singh under the supervision of W. Roberts ;
Family Budgets (1932-33) *of Four Tenant Cultivators in the Lyallpur District* (1933) by Kartar Singh.
(All publications of the Punjab Board of Economic Enquiry.)

Other studies of a similar type include a study of the financing of the cotton crop, one of the earlier economic investigations financed by the Indian Central Cotton Committee. There is now the very large Marketing Section of the Imperial Council of Agricultural Research with the Agricultural Marketing Adviser—A. M. Livingstone—as its head, which recently published its first intensive survey, *viz.*, of wheat marketing. Surveys of the marketing of other crops are following in rapid succession. Other Departments of Government especially the Co-operative Departments are deeply interested in Agricultural Economics. The journals of the Co-operative movement contain in almost every issue some studies of this important subject.

In the Bombay Presidency fruit marketing had been (previous to this) the subject of study by both official and non-official agencies resulting in a *Report of the Committee on the Improvement in the Marketing of Fruit and Vegetables in the town of Bombay*, 1934 (written up by G. S. Cheema and T. G. Shirname) and *A Survey of the Marketing of Fruit in Poona* by D. R. Gadgil and V. R. Gadgil.

XII. Conclusion and Anticipation.

The preceding eleven sections will, it is hoped, have given some idea of the manifold activities of agricultural research workers in India and of how these activities have grown from few to many and from simple to complex.

Is there anything in the past history or the present situation that can enable us to prophesy even generally the course of events in the future ? We may perhaps venture a few forecasts :—

(1) We may expect a greater and more effective co-ordination of agricultural research throughout India, at the same time leaving sufficient elasticity for the genius of individual workers and for adaptation to local conditions. The recently organized meetings of dry farming research workers and horticultural research workers

in India are indications of such a trend. In arranging such co-ordination the Imperial Council of Agricultural Research is bound to continue to play an important part.

(2) We may also anticipate a much closer connection between pure genetics and plant-breeding with obvious advantages to both. This means the training of practical plant-breeders in advanced genetics and the utilization by plant-breeders of the material of their plant-breeding work for the further advance of genetic theory.

(3) We may look for a much closer connection between plant physiology and mycology, entomology and manuring. In all the work dealing with plant diseases and nutrition the necessity for a physiological background and a knowledge of physiological technique is becoming more and more apparent, while at the same time the sphere for the plant physiologist who is a plant physiologist and nothing more seems to be rather limited so far as agricultural science is concerned.

(4) We may expect the still greater extension of the application of statistical method to all branches of agricultural research.

(5) We may be certain of the development of a really large-scale organization of propaganda methods whereby the proved results of scientific investigation shall be quickly transferred to the cultivating population ; and finally

(6) We hope for the development of agricultural economics in such a manner as to give a clear lead to the ways whereby the lot—physical and spiritual—of the cultivator may be improved and the full benefit of scientific investigation may be allowed to reach him.

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PROGRESS OF VETERINARY RESEARCH IN INDIA DURING THE PAST TWENTY-FIVE YEARS.

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CONTENTS

I. GENERAL REMARKS.

In introducing a review of Veterinary Research for the past 25 years one is immediately faced with the problem as to what

particular subjects should be included within the purview of such a review. Should one confine the term Veterinary Research to those sciences which may be described as falling under the comparatively restricted terms of Animal Pathology or Animal Medicine, as was the tendency at the commencement of the period under review, or should one look upon Veterinary Research as including all those sciences which form the background of the more comprehensive terms of Animal Health or Animal Husbandry ?

The decision has been made in favour of the latter, for of recent years it has become only too apparent that medicine, either human or veterinary, cannot advance alone, but must be accompanied by concurrent researches in the sister sciences of genetics and nutrition, if sound and lasting progress is to be made.

The importance of good animal husbandry to such an excessively agricultural country as India, in which cattle are the chief motive power, besides supplying milk and *ghee* to a diet which is otherwise largely vegetarian, is too obvious to need further stressing, and the fact that she has been overrun from time immemorial by some of the most devastating cattle plagues existing no doubt led to the concentration of effort which is noticeable in 1911, the year when this review commences—to provide means of combating these plagues.

At that time some practical cattle breeding was in progress, notably on Government farms at Hissar and Chharodi, by the Civil Veterinary Departments of the Punjab and Bombay respectively, and the now famous Pusa herd of Sahiwal cattle had been established at the Imperial Agricultural Research Institute, but most attention was being paid to the development of the Imperial Veterinary Research Institute, Muktesar, for the prevention of contagious diseases amongst animals, and it is interesting to note that it was in 1911 that use was first made of plains buffaloes at Bareilly for the preparation of anti-Rinderpest serum, and the initial steps were taken for the purchase of the Izatnagar Estate near Bareilly, which is now being rapidly developed as a branch of the Muktesar Institute, for the location of sections dealing with the commercial preparation of biological products, Animal Nutrition and Poultry Research.

The total number of doses of sera and vaccines issued from the Muktesar Institute for the prevention and diagnosis of animal diseases in 1910-11 was 6·34 lacs. This quantity rose to 35·16 lacs of doses in 1920-21 and reached its maximum of 75·86 lacs in 1929-30. As some of the provinces have now made arrangements to prepare their own biological products, particularly Rinderpest vaccine, the issues from the Muktesar Institute are now falling again and amounted to the comparatively small total of 37·28 lacs of doses in 1935-36.

It will thus be seen that the Muktesar Institute, by reason of the great demand for its products from the different provinces and

States, and also the Military Department, inevitably developed into an enormous production centre, and until a few years ago there was a great danger of its research activities being seriously interfered with. By transferring all the work connected with the manufacture of its major products to Izatnagar this difficulty has now been overcome, but in evaluating the results of the Muktesar Institute the facts recorded above should be borne in mind.

Actually the results of a research institute may quite legitimately be considered under two heads, viz. :—

(*a*) the output of scientific literature, and
(*b*) the application of laboratory results in the field.

Under the first head, for the reasons given in a preceding paragraph, the publications of the Muktesar Institute have been somewhat spasmodic, but since research workers at Muktesar have been organized into appropriate sections and relieved to a large extent of any work in connection with the manufacturing side of the Institute, the number of scientific publications has steadily increased and their subject matter now covers a very wide field.

It is in connection with (*b*), however, that the most striking success during the past 25 years has been obtained, and in the matter of disease control, particularly of the major plague Rinderpest, it may be claimed that Veterinary Research in India has produced results comparable with any other scientific service in the world.

In this connection it should be pointed out that at present there is no legislation in existence in India for the control of bovine contagious diseases, except some of limited application in Madras and Burma, so that the results have been obtained entirely through the development and use of biological products and the efforts of field workers, whose numbers, for such a large country, have been and are still very small.

The total number of gazetted staff employed in the Civil Veterinary Departments in India in 1910-11 was 36, and this has gradually expanded to a total of 147 in 1935-36. The subordinate staff employed in 1910-11 amounted to 955, which number has now been increased to 2,085, but it will be seen that this is still far short of what is required for the proper application to the field of the results of Veterinary Research throughout the whole of British India. The Royal Commission on Agriculture of 1927 placed the amount of Veterinary staff required for British India at 300 officers and 6,000 subordinate staff.

Research into the cause and prevention of animal diseases has not been confined to the Muktesar Institute. During the second half at least of the period under review, considerable attention has been paid to these problems at the laboratories attached to the provincial Veterinary Colleges, notably in Lahore and

Madras, and when one remembers that the officers working in these laboratories have also to perform teaching duties, it will be admitted that their contributions to science have been no small accomplishment.

During the same period Veterinary Serum Institutes have been established by the Mysore and Madras Governments for the manufacture of sera and vaccines used locally, and more recently the Imperial Council of Agricultural Research has given a fillip to this subject by providing the funds for a Veterinary Disease Investigation Officer in each British Province and Hyderabad State. This team of field investigators has brought to light a large amount of new material awaiting deeper study by properly equipped research institutes, not only in matters relating to epizootic and enzootic diseases, but also in the nutritional field and in connection with breeding problems.

The science of Animal Nutrition did not attract any attention in India until the comparatively late date of 1913, when as a result of a recommendation of the Board of Agriculture, a movement was set on foot to recruit a Physiological Chemist to undertake researches in this subject. Unfortunately it was some years before this officer was able to commence work, so that the output of literature in this science has not been very great, but this is an omission that is likely to be rectified in the near future, for arrangements have now been made to set up an organization which should soon be in a position to supply more adequately the needs of the country in this subject. The Central Institute for Animal Nutrition Research will be located at Izatnagar as a Section of the Imperial Veterinary Research Institute, thus bringing together workers on both the normal and abnormal processes of the animal body, and research stations for the investigation of more local problems will be located at Coimbatore in the south, Lyallpur in the north, and Dacca in the east.

A reference has already been made to some of the earlier efforts to improve the indigenous breeds of cattle in India, and the number of cattle farms has steadily increased throughout the period under review. The work being done, however, must be considered as largely practical in character, devoted either to the production of a good working bullock, an economic milch cow, or in some cases both, and it has not yet been possible to set up an Institute of Animal Genetics where a more scientific study of the many problems involved might be investigated.

For the preparation of the more detailed accounts which follow, great help, which is gratefully acknowledged, has been received from the following gentlemen :—Mr. Wynne Sayer ; Dr. K. C. Sen ; Mr. J. F. Shirlaw ; Captain S. C. A. Datta ; Dr. H. N. Ray ; Messrs. Riazul Hassan ; S. K. Sen ; P. R. Krishna Iyer ; and H. D. Srivastava.

II. Bacteriology and Immunology.

During the early part of the period under review, the Imperial Veterinary Research Institute existed primarily as a serum Institute concerned with the eradication, or control, of that scourge of cattle in tropical and semi-tropical regions—Rinderpest. But while Rinderpest always maintained its place of importance, practically every disease to which animal flesh is heir has come into the field of bacteriological research at Muktesar, some with an intensity governed by the critical needs of the moment, others with a slower, but none the less praiseworthy and persistent attempt at elucidation and control.

Naturally, in a country where the bovine in all its expressions of productivity is fundamental for existence, the activities of research have been primarily directed towards the control, and, where possible, the eradication of bovine disease, but the following review will show that where animal disease has existed, no matter what the species of animal affected, or the economics of the situation, the Institute has rapidly come into the field with a helping hand.

It is an invidious task to try and decide which advances in the subject of immunology during the past 25 years can be attributed solely to researches carried out in India, except in the case of those diseases peculiar to the animal population of this country. It is gratifying to note, however, that the services rendered by the very meagre veterinary personnel all over the country have been immense when viewed in the light of the magnitude of their task. In spite of there being a large variety of impediments and obstacles in the way of success, such as the peculiar, inherent, ethical sentiments of the average livestock owner in India and his gross ignorance of the method of preventive inoculation as a means of control, which tend to produce in him a strange psychological state of inertia and apathy towards veterinary innovations, coupled with want of sufficient staff and funds and absence of suitable legislative enactments for the control of the movements of livestock, the evidence grows in volume and trustworthiness every year that the progress achieved in veterinary immunology, both in the laboratory and in the field, has been consistent, if nothing more, with the facilities available from time to time.

The laboratory work has been done almost entirely at the Imperial Veterinary Research Institute, Muktesar, with the help of some valuable additions carried out in the provincial laboratories attached to the Veterinary Colleges of the Punjab, Madras and Bengal and the Mysore Serum Institute. The researches conducted have been of an essentially practical and economic rather than of an academic character and the Imperial Institute of Veterinary Research was soon transformed from the pure research laboratory, that it was at its inception, to a large scale manufacturing undertaking, producing, with as simple and humane a technique as

possible, cheap and effective sera, vaccines and diagnostic products issued with full instructions for their use to the field veterinary authorities.

It is not possible to deal, in full justice, with the progress made in all the various spheres of veterinary preventive medicine within the compass of a few pages, but, in what follows, an endeavour is made to present the most outstanding advances effected in the control of some of the more important contagious maladies of live-stock in India.

A word may be said here in regard to the various products that have been devised to combat such diseases. These fall into two well-defined categories :—

(*a*) *Protective substances*—such as anti-sera, vaccines, and living, virulent or attenuated viruses, which afford a temporary or a more or less permanent immunity against the specific organisms, and

(*b*) *Diagnostic agents*—such as tuberculin and mallein, which act through the development in the infected animals of a hypersensibility to the proteins of the specific organisms.

In addition, certain serological tests based on well-known immunological principles, e.g., the agglutination test, are also employed to determine the incidence of some diseases.

(*a*) *Rinderpest.*

This disease, which is of paramount importance to livestock owners in India, has formed the major problem for investigation in India throughout the period of review. The endeavour so to alter the natural soil that the seeds of disease, far from destroying it, shall actually improve its quality, is the aim of modern prophylaxis, and the present conception is that 'no animal need die of Rinderpest'.

Antiserum

Antiserum in this country was first prepared in 1899 by Rogers, following closely upon the work of Turner and Kolle in South Africa, by using hill bulls as serum producers; later, plains cattle, and then buffaloes were introduced. The Serum-Alone method, which was once a very popular method of combating the disease, is now going out of fashion, though the present method of preparation has almost reached perfection in the matter of obtaining a highly potent product free from external contamination. All attempts at satisfactory cultivation of the infective agent outside the body having failed, each brew of serum manufactured is tested for safety and potency on hill bulls infected with a known dose of the virus.

Among a host of other points, much precise information has been obtained upon the relative susceptibility of different breeds

and classes of cattle to rinderpest and the amount of serum required to protect them against it, the most suitable conditions and agents for the preservation of serum, the anti-body content of different fractions of serum proteins, and the effect of heat on Rinderpest immune bodies. Researches upon the fractional precipitation of the immune bodies have been conducted with a view to concentrate the serum for economy in transport and for standardization of its potency, and it has been found possible even to desiccate the serum completely without appreciable loss of potency.

Virus

Very extensive researches have been conducted to study the biological characteristics of the infective agent and the effect of various factors on its viability outside the body, with a view to obtain information to enable its being sent out to long distances from 'virus stations' in a living, virulent state for purposes of active immunisation. The virus can easily be propagated in susceptible cattle, but the blood of these animals when used in the immunisation of stock by the well-known and highly advocated 'Serum-Simultaneous method' for the conference of an active, lasting immunity, is attended with a serious risk of conveying other blood parasites (piroplasms) which bring about a fatal intercurrent infection in the inoculated animals. Determined efforts were made by Edwards at Muktesar to implant the virus in hosts other than cattle (rabbits, goats) and it was as a direct result of these intensive researches that we now have the so-called 'fixed goat virus', which is not only free from bovine piroplasms, but is also a much attenuated form of the virus. Consequently, the protective dose of serum required against this form of the virus is negligible and it has already been applied in several Provinces on an extensive scale as a vaccine without any quantity of antiserum. This has simplified the technique of operation and reduced considerably the cost of immunising cattle against rinderpest, and it is expected that in the coming years more and more animals will be subjected to immunisation by this method.

Vaccines

The general experience after extensive trials in this country with various vaccines, such as Kelser's chloroform vaccine, Daubney's formalinised vaccine and Gerlach's dried vaccine, during the early part of the last decade, was that the administration of vaccines which produce a reliable immunity is attended by a considerable amount of risk, in that a certain proportion of animals so treated may develop a severe or even fatal infection, whereas in those cases where the vaccine is safe, the immunity conferred is unreliable and of comparatively short duration.

Immunity Researches

The system of control of rinderpest recommended for adoption in India has been to eliminate the disease not by killing the diseased and in-contact animals, as was done in South Africa and

other countries, but by raising the natural resistance of susceptible animals to the disease by the most reliable and economic methods of conferring an active and lasting immunity. From extensive researches conducted at Muktesar and from the vast number of immunisation operations carried out in the field, a large volume of evidence has been collected on the best methods of immunising stock, the nature and duration of immunity conferred by various forms of the virus, the nature of the immunity following upon different grades of reaction undergone by the animal at the time of immunisation, and the importance of age, breed, and various other factors in determining the quality of the immunity produced. Information has also been gathered on the susceptibility of very young calves to the disease, the influence exerted on the natural resistance of calves by immune dams as compared with non-immune dams, and the optimum period for reinforcing immunity in calves immunised at very young ages.

(b) *Hæmorrhagic Septicæmia.*

It is a matter of conjecture whether Rinderpest or Hæmorrhagic Septicæmia is the more important bovine malady in India. Certainly these two diseases vie with each other in importance as fatal diseases of cattle causing serious economic loss. One important aspect of hæmorrhagic septicæmia is that it frequently occurs at that season of the year when the farmer most needs the services of his draught bullocks and the calamity ensuing on an outbreak of this disease in an agricultural community can readily be understood.

The history of the activities of Muktesar is, therefore, intimately linked up with the history of hæmorrhagic septicæmia, and one can look back on the past with satisfaction and to the future with increasing confidence, that the application of research devoted to this disease problem has resulted in far reaching methods of control, which, if judicially applied, will give the humble peasant toiling in the field, a reasonable security of existence. And to the owner of larger herds, in which individual animals are of greater intrinsic value, and the conservation of which is of immense importance if any progress in the raising of pedigree stock is to be made, the prospects of success are even greater.

The Imperial Institute, as the result of its researches into hæmorrhagic septicæmia, is in the position of being able to issue two highly satisfactory biological products for use in the field. The first and the most frequently used is an anti-serum, first prepared from cattle by Lingard in 1905, and now prepared from buffaloes by hyper-immunisation with selected strains of the causal organism of this disease. These strains have been recovered from natural outbreaks in the field and represent the average types of infection to which cattle are susceptible. The ultimate proof of

the efficacy of such an anti-serum exists in the demand for it, and this demand has shown a steady increase since the time it was first made available.

A second line of attack in this disease, and one of equal merit, is the production of a polyvalent vaccine. Serum treatment of animals which are in contact with the disease, valuable though it be to tide the animals over the critical phases of infection, confers no degree of immunity sufficient to protect a herd during a seasonal outbreak which may extend for three months or slightly more. It is for this reason that a vaccine has been evolved. This vaccine is prepared from selected strains of the organisms isolated from natural outbreaks and is therefore polyvalent. When occasion demands, e.g., when it is known that disease in an area is due to one particular strain, as occasionally happens, a single strain vaccine (monovalent) may be manufactured to meet the needs of the occasion. The use of this vaccine confers a valuable degree of immunity in cattle herds exposed to infection, and the degree of immunity induced is generally sufficient to protect animals over one season.

(c) *Anthrax.*

Anthrax, as is well known, usually occurs in a sporadic form, but in this country virulent enzootic outbreaks are sometimes encountered and this has raised a most difficult problem from the point of view of producing immunity in susceptible herds.

Research into the problem of Anthrax control has been rendered difficult by the existence of many strains of the Anthrax organism. Strains, isolated from virulent outbreaks, have rapidly lost their virulence and antigenic properties when maintained under laboratory conditions. It has not been exceptional, for example, to encounter strains which become after a few subcultivations on nutrient media, entirely apathogenic for the highly susceptible laboratory animals used. Further, apart from the question of varying virulence and antigenic potentialities, it would appear that the range of susceptibility of farm animals in India is a wide one, and that any vaccine, to be safe, must be prepared strictly in accordance with the known variations in susceptibility.

Every known method of immunity production—and their name is legion—has been given a generous trial under exacting field and laboratory conditions, and it would appear from this experimental work that Anthrax in India shows so many peculiarities in expression of epizootiology that the problem of producing a satisfactory degree of active immunity is well nigh insoluble. The difficulty has been partially circumvented by the production of an anti-anthrax serum, prepared from cattle. That this serum does yield a measure of protection is undoubted. The demands for it

from the field indicate its general usefulness and yet it cannot be considered an effective substitute for a vaccine which will confer immunity for a reasonable period, say one year.

The year 1936, however, dawned on a more hopeful outlook, and it is hoped that the use of a spore vaccine, which has already been successfully exploited in other tropical countries like South Africa and Burma, may provide a solution to the problem of anthrax immunity, not only in the bovine, whose needs are primary, but equally in all species of animals.

(*d*) *Black-quarter.*

Black-quarter—erroneously termed 'symptomatic anthrax', a disease with which it has no connection apart from the fact that it is a cause of sudden illness and rapid mortality—is widespread among cattle throughout India. The cause of the disease is usually stated to be an anærobic organism, *Clostridium chauvoei.* While it is generally accepted that this organism, one of the important gas gangrene group, is in the majority of outbreaks primarily causal, extensive researches conducted at Muktesar agree with research in all countries where attention has been focussed on the disease, which have shown that *Cl. chauvoei* represents only one of a group of organisms which are capable of producing outbreaks of Black-quarter. Research has therefore been directed towards an accurate determination of the various species of anærobic organisms encountered in clinical Black-quarter and a considerable volume of accurate information has been gained.

Unlike Anthrax, in no way do the varieties of infection and their clinical manifestations differ in India from those described in Western countries. The relative incidence of infection of the varying types of infection is comparable, and as *Cl. chauvoei* is known to be the cause of most outbreaks and sporadic cases, researches in the field of immunity have naturally been directed against disease caused by this organism. The fact must not be overlooked, however, that in consideration of the losses caused by pathogenic anærobes other than *Cl. chauvoei*, the Institute has kept pace with the steady progress exhibited among research workers of all countries where Black-quarter is rife and this malady is accorded the degree of scientific attention which it peculiarly merits.

Two products, directed towards the control of Black-quarter in the field, a vaccine and a serum, are issued from Muktesar. The vaccine is a formalinised spore-vaccine prepared from authentic strains of *Cl. chauvoei* of Indian origin after the method of Leclainche and Vallée in France. The serum is a hyperimmune one prepared from buffaloes. That both products are of great value in their

particular sphere is amply indicated by their universal and increasing demand throughout India.

(e) *Tuberculosis.*

In view of the increasing attention paid to the study of human tuberculosis during the last two decades and the well-known relationship of bovine and human tuberculosis, tuberculosis of animals has been a subject of intensive study. The opinion has been generally expressed that Indian cattle are rarely victims of tuberculosis, if not relatively refractory in comparison with the cattle of Western countries. It is probably true that, under average conditions, where Indian cattle are kept out of doors, little tuberculosis exists and the risks of spread through a herd are slight as compared with the cattle of Western countries, where the conditions are particularly favourable for the dissemination of infection. That tuberculosis, however, is not infrequent among Indian cattle maintained under the relatively ideal system of an open-air life and that it is a disease to be seriously reckoned with in-housed and stall-fed cattle of the cities, is a fact of increasing recognition and importance. Data concerning the incidence of tuberculosis in cattle in urban areas reveal a disquieting position, and while mammary tuberculosis may not have assumed the proportion and the significance that it has in cows in Western countries, the fact must not be overlooked that, apart from any disease of the udder, an infected cow may excrete tubercle bacilli in the milk.

The incidence of tuberculosis in cattle has largely been determined from abattoir figures and although it is not judicious to accept such figures as being representative of the average general incidence, they are sufficiently alarming to make us review our opinion of the susceptibility of Indian cattle to the disease. As the results of carefully controlled tuberculin tests on closed herds, it has been found that the disease exists to a degree which warrants a very intensive investigation, and during the last two decades some very valuable data concerning the incidence and types of the disease have been collected from all provinces of India.

History

Bovine tuberculosis must have existed in this country for a long time but the earliest recorded case traced so far dates back only to 1898. While the experience of the early workers indicated that the disease was very rare among Indian cattle, and the lesions were invariably minute in extent, localized in particular tissues, and retrogressive in their appearance, slaughter-house statistics collected in 1927 revealed an incidence of 16·28% and the figures of 1931 showed 21·3% cows, 23·6% buffaloes, and 31·6% bullocks as affected with gross lesions. The disease is no longer restricted to urban areas or to any part of the country, and numerous cases have now been detected among animals of all species.

Experimental investigation

The first experimental investigation upon bovine tuberculosis in India may be said to have started with the researches of Glen Liston and Soparkar in 1917. The work was directed to obtain an explanation for the alleged rarity of the condition, and while they attributed it to a natural resistance to the disease possessed by Indian cattle, the later experiments of Sheather appeared to show a relatively low degree of virulence of the causal organism isolated locally. The subject was next discussed at a meeting of veterinary officers held in Calcutta in February 1923, and by the Board of Agriculture at its meeting at Pusa in 1925. The latter body passed a resolution recommending certain steps to be taken for the prosecution of research on bovine tuberculosis, and in the meantime the Indian Research Fund Association had been persuaded to supply funds and to depute an officer for carrying out at Muktesar a Bovine Tuberculosis Inquiry for a period of five years, 1923–1928.

The experiments undertaken in this inquiry showed that while some of the indigenous cattle displayed a high resistance to the organism, others succumbed as quickly as European animals would have done under the same conditions, and it was found that generally speaking the indigenous breeds did not possess more resistance to the disease than animals possessing a large admixture of European blood. The organisms obtained from natural bovine lesions appeared to be as virulent as those in other countries. The above inquiry added some valuable information to our knowledge but many important questions still remain to be solved.

Evidence has been collected at Muktesar from a Dairy Farm and two Remount Depots, and from two Zoological Gardens to show that after introduction of infection, a high incidence of clinical tuberculosis may develop in a herd maintained under certain conditions of housing. In studies carried out at Madras, a high incidence and generalized lesions were recorded among the conservancy bullocks. Records exist of about half a dozen cases of tuberculous mastitis in buffaloes and cows in this country, and occasional samples of milk from such animals have shown the presence of the specific bacilli.

Bacteriological work

The available results of bacteriological work carried out upon lesions of tuberculosis in animals in India show that the bovine type of organism is commonly associated with bovine lesions, and the human type with the disease in pigs. The avian type of organism has also been recovered from a bullock and some pigs, and the bovine type from a pig, a goat, several llamas and buffaloes. The human type of *B. tuberculosis* is usually believed to be responsible for the disease in man in this country. Two cases of naturally acquired tuberculosis in cows caused by the human bacillus have, however, been recorded, and similarly one or two cases of human tuberculosis of bovine origin have been detected.

The diagnosis of the disease may be arrived at during the life of an animal from the clinical signs of the disease or by the use of the diagnostic agent Tuberculin, which is prepared at the Muktesar Institute. Difficulty has been encountered in interpreting the results of the subcutaneous test with this agent owing to diurnal fluctuations in temperature shown by animals in this country, and better results have been obtained with the Double Intradermal test, but further work on the standardization and elaboration of a more specific tuberculin is urgently required.

(*f*) *Johne's Disease.*

Johne's disease is caused by another acid-fast bacillus and the main seat of multiplication of the organism is the mucous membrane of the intestines, particularly the ileum and the cæcum. Although it is generally stated that the first case of the disease in India was recorded by Sheather in 1917, the classical book on the subject by Twort and Ingram, published in 1913, mentions an earlier case at Lahore on the authority of Meadows of the Punjab Veterinary Department. A remarkably large number of records of the occurrence of the disease in all parts of the country, is now available. Cattle, buffaloes and goats are affected and recently the disease has been detected in an animal from the interior of the Garhwal hills where the possibility of contracting infection from imported animals was remote.

The very insidious onset of Johne's disease makes its presence in a herd a most dangerous one, particularly in farms which are heavily stocked. Diagnosis in life is arrived at by the use of Avian Tuberculin, by the microscopic examination of bowel washings, collected by a method elaborated by Krishnamurti Ayyar in Madras, and of fæcal or rectal smears. In the earlier tests, *Johnin* and *Paratuberculin*, obtained from other countries, failed to give as reliable results as the Avian Tuberculin issued from Muktesar, but *Johnin*, prepared at this Institute by improved methods, is now under test. Compared with cases in Europe, a larger proportion of cases in India show a complete absence of clinical symptoms or are retrogressive when brought under new conditions. The influence of parturition in precipitating a crisis in cases of Johne's disease has been repeatedly seen in first calvings, and experience has been gained to show that other factors like mineral deficiency may play a part in the sudden breakdown of an animal's protective mechanism. Data have been collected to show that while the incubative period of the disease in adult animals may be as long as 6–9 months, that in suckling calves may be only a few weeks. Work carried out at Muktesar has failed to confirm the possibility of the bacilli being excreted through the lactating udder, or of the disease being transmitted *in utero*.

Some work has been carried out with a view to cure the disease by bacteriophage, non-specific protein therapy, and formalin injections, but while a betterment in the physical condition of treated animals has been observed, the possibility of sterilizing the animal completely of the bacilli by drugs does not appear to be practicable. However, on the analogy of the specific action of chaulmoogra oil and its esters on the leprosy bacillus, another acid-fast organism, experimental treatment of clinical cases has been tried in England and America, and the work is now being repeated in Mysore. Large scale experiments have been carried out to study the vaccinating relationship of the avian tubercle bacillus and Johne's Disease, but a set-back resulted from a somewhat high mortality in vaccinated animals due to an unanticipated and surprisingly high virulence of the strain employed.

At Muktesar a special Johne Herd has been built up since 1931. In addition to employing the animals in this herd for standardizing brews of Avian Tuberculin periodically, observations upon several aspects of the disease are being made. Alternate newly born calves are being vaccinated within a few hours of their birth with a standardized living culture on the lines of Valée and Rinjard's successful work in France, but so far the experience in India regarding the efficiency and safety of the vaccine has been disappointing. Other researches on this disease have been concerned with improvement in the culture media, methods of diagnosis, testing the viability of the organism under natural conditions and to determine if any small animals are susceptible to this infection and are likely to be useful as test animals for laboratory work, but no outstanding results have been achieved.

(*g*) *Bovine Abortion.*

Bovine abortion has not assumed the same economic significance in India as in other countries where more intensive stock farming, line breeding, high milk production and closer herding render animals both more susceptible and more liable to infection.

In this respect, Indian cattle, generally, are particularly fortunate. In indigenous herds, brought up in the open, the incidence of the disease is immaterial. In pedigree herds, especially those containing a fair percentage of imported blood, and in selected dairy herds maintained under housing conditions and yielding a milk supply comparing not unfavourably with the herds of Western countries, the problem of the incidence of infection with bovine abortion is one of increasing importance. This problem is complicated by the known mineral and vitamin deficiency to which cows in India are subject. Researches at the Muktesar Institute have been directed to both sides of the problem, the nutritional as well as the bacteriological.

It has been found that Indian cows are as susceptible to infection with the specific organism of the disease, *B. abortus* Bang, as cattle of any other country and, given favoural spread of infection, the problem of combating bov become as acute in India as elsewhere in the world. Over a period of many years, work at the Muktesar Institute has been directed towards an accurate assessment of the degree and type more especially in selected herds throughout India, and very va able data have been secured. Accepting from these researches that Bang's bacillus is the predominant cause of abortion in cows in India, experimental vaccination, pursuing all recognized lines of vaccine therapy, has been given an exhaustive trial.

The results have been as discouraging as in other countries concentrating on this particular field of research. Live vaccine has been issued from Muktesar on occasions when the incidence of infection appeared on the upward trend in certain herds and where the frequency of abortions demanded its use. Otherwise, a dead vaccine, comprising as many strains as possible from natural cases, has been used with results that can only be termed equivocal.

The pure bacteriology of the disease, the typing and classification of organisms of the Brucella group isolated from clinical cases of abortion, work which is at the moment of academic interest, but nevertheless of immunological value, has resulted in the collection of many strains of Indian origin. The biochemistry and the grouping of these strains have occupied many assiduous hours in the laboratory.

The note on this subject would not be complete without a reference to the prevalence of an allied infection in goats, due to *Brucella melitensis*. In the Punjab, as the result of extensive investigation, infection of goats with this organism is considered to be in the proximity of 50 to 60% in all herds. Such herds are occasionally victims of abortion consequent on the infection, but investigation has shown that this aspect of the infection is not so serious as in cattle. The most serious implication lies in the fact that the entity of human undulant fever is now well established in India. An epidemic of the disease occurring in British and Indian troops was investigated in Northern India and proved to be due to *B. abortus* Bang infection, and accumulating evidence points to the widespread existence of human undulant fever related to infection with Brucella organisms of bovine and caprine origin.

The nutritional aspect of non-specific abortion is one that has gained increasing importance, and its study during the period under review and at present constitutes a subject of major research on the part of the biochemical staff of the Muktesar Institute.

(*h*) *Bovine Mastitis.*

Methods of selective breeding of the high yielding strains of dairy cattle are being increasingly adopted nowadays in India,

and the incidence and liability to udder affections have become considerable. Experience in other countries shows that as a result of udder affections, serious economic loss is suffered by dairy farmers in having to maintain animals which have been rendered progressively uneconomical, due to the partial or complete destruction of the functional mammary tissue, and the constant anxiety in public health work which such animals cause by their potentialities as the source of epidemics of severe illness and even death among human subjects, due to milk-borne infections of udder origin, e.g., scarlatina, sore throat, etc. In India cases of mastitis of various kinds have no doubt been encountered from time to time, occurring either sporadically or in series, but no exact data regarding the various micro-organisms present in the secretions of the udder in cases of mastitis are available.

Hæmolytic and non-hæmolytic strains of *Staphylococcus aureus* have been recorded from the majority of cases, and a highly hæmolytic strain of coliform organism has been isolated from a few cases, whereas in some instances only a hæmolytic streptococcus has been cultivated. In the Muktesar Dairy a number of first calf heifers have been found to carry their calves overtime with marked œdema of the udder, while signs of mild mastitis often accompanied with the passage of blood in the milk were exhibited at the time of calving.

Measures for the rapid diagnosis in the field and in the laboratory, and for efficiently combating, by segregation and chemotherapeutic measures, udder infections are now available. To what extent these are applicable to Indian conditions remains to be seen as opportunities occur.

(*i*) *Bovine Lymphangitis.*

This disease was first seen in Bengal, and is known to occur in the Madras Presidency as well. In the earlier work Holmes incriminated a streptothrix as the causative agent, while Raymond attributed the disease to a bacillus. Sheather's studies at Muktesar in 1921 revealed a rod-shaped organism as the cause, which finding was generally confirmed by Krishnamurti Ayyar in 1927. The latter considered the disease to be identical with plague of man, and the geographical distribution of the cattle disease in Madras was shown to be similar to that of human plague. Krishnamurti's later studies, however, showed that the organism responsible is another *Pasteurella—P. pseudo-tuberculosis rodentium type II* of the Lister Institute. This finding has been confirmed at Muktesar, and a vaccine prepared from the organism has been used in the field for the last few years with success.

(*j*) *Sheep and Goat Diseases.*

A number of very interesting, though somewhat obscure, conditions have been reported from time to time. Contagious ecthyma

of goats, characterized by a pustular dermatitis of the perioral region and the buccal mucous membrane and believed to be due to a virus in association with certain bacteria, has been reported from several provinces. Caseous lymphadenitis of sheep due to the Preisz-Nocard bacillus has been recorded from the Punjab and Hyderabad State. Frequent cases of purulent peritonitis in goats have been met with, and *Corynebacterium pyogenes*, sometimes accompanied by *Streptococcus anginosus*, has invariably been found associated. A form of contagious pleuro-pneumonia of goats known as *Dokari*, which is of considerable economic importance in some parts of the country and is controlled by villagers by a rough method of immunisation, consisting in the insertion subcutaneously of portions of the lungs from affected cases into healthy animals, has been the subject of some research into its etiology, but so far it has defied solution.

(*k*) *Glanders*.

This disease of equines is widespread in India but the available figures give little idea of the actual incidence. Cases of suspicious glanders, seized under the Glanders and Farcy Act by provincial veterinary departments, are usually reported on account of well-defined clinical symptoms. Annual surveys of the tonga-pony population of one town in the Punjab (Lahore) revealed a disquieting prevalence of the non-clinical form of glanders, cases which were ordinarily not reported by the veterinary inspectors responsible for such work. It should be stated that, in many instances, non-clinical cases were in good average condition, no suspicion of the disease being present. As a matter of routine, army horses are subjected to periodical examination for the disease, but such arrangements do not ordinarily exist in the provinces.

We are in possession of a biological agent of repute—mallein—which, judiciously and extensively employed, should effect a radical control of this serious equine disease. One fact worthy of note is that very few cases of human beings (*Syces*) becoming infected are on record, but two research workers in this country, Gaiger and Shilston, were unfortunate enough to contract the infection, the latter fatally, in the course of their laboratory work.

It would appear that the Indian strains of *B. mallei* are of a lower grade of virulence than the Western strains, a fact which is borne out by the feeble and occasionally negative Strauss reaction in Guinea-pigs after intraperitoneal inoculation with authentic strains of *B. mallei* freshly isolated from lesions of the disease. Mallein is prepared at the Imperial Institute, both the subcutaneous and I.D.P. varieties. It is now specially standardized on artificially infected horses. Prior to this measure, it was found that, occasionally, brews of mallein gave non-specific reactions which evoked great difficulty in the interpretation of the test, but

now that particular attention has been paid to the standardization of the product, this difficulty has been overcome. Modifications of the original mallein have been experimented with, but in all cases, these modifications were found inferior to the original formula.

The experimental treatment of glanders has been attempted in the Punjab. A highly potent antiserum prepared from horses was shown to possess remarkably retrogressive effects in the cutaneous form of the disease with general improvement in the condition of the affected animals. Such cases continued to show a positive mallein reaction, however, attended by relapse when serum treatment was discontinued.

There is some evidence available in India to show that *B. whitmorei* (Stanton and Fletcher) is occasionally responsible for glanders-like lesions in horses, and on one occasion at least disappointing results in the routine production of mallein were ascribed to the organism from which the product was prepared conforming more in character with this organism. On two occasions *B. pseudotuberculosis rodentium* was recovered from clinical cases reacting to mallein. From neither of these animals could authentic *B. mallei* be isolated.

(*l*) *Strangles.*

Strangles is a universal disease of young horses in India. In the army remount establishments it assumes a virulence and incidence of such degree as to cause serious loss. This loss is not only expressed in terms of actual mortality but also—and to an even greater extent—in protracted debility resulting from the set-back in growth and health consequent on the disease. The percentage of three-four year old horses rejected by the army authorities is governed to a very large extent by the incidence of strangles and its sequelæ in the horse-breeding areas.

Research has, therefore, been directed to the control of the disease by means of vaccines, antisera and pharmaceutical agents claimed to be of advantage in streptococcal infections generally. Field experiments have been launched on a large scale, the experimental work conjointly taking effect from the Muktesar Institute and the actual disease outbreak in the field. Experimental vaccination has proved of little or no avail, however the vaccines are prepared. At one time, hope was centred in the use of Besredka's antivirus and pyovaccination. These experiments, which gave an early promise of success, were later abandoned when a more extensive trial of this method was made. Similar negative results have been obtained with killed, heated and chemically treated vaccines. Ether-extracted vaccines prepared from several strains of *Streptococcus equi* isolated from field outbreaks yielded mildly encouraging results which were, later, not confirmed.

It appears, from the records of field experiments, that orthodox methods of vaccination in this streptococcal disease of equines, are singularly unsuccessful. On the assumption that Strangles may be primarily a virus disease, followed by streptococcal infection of varying types, the serumisation of in-contact horses during an outbreak has been attempted. The serum, obtained from recently recovered cases in the afebrile phase, was found to possess no prophylactic value.

Drug treatment has proved a dismal failure, even when administered during the earliest stages of the disease. Among the numerous agents to which a trial was given may be mentioned: the flavine series, Lugol's iodine intravenously and intratracheally, omnadin, antibacysn, tryparsamide, S.U.P. 36 and Prontosil. Simple medicaments such as salicylates combined with good nursing, have given as satisfactory results as could be hoped for and in no manner inferior to those agents for which a more specific effect is claimed.

Further experimentation with this condition has recently been given fresh impetus by the important finding that it is possible to confer a mild attack of the disease by the inoculation, usually intranasally, of cultures of certain selected strains of the *Streptococcus equi*. Herein lies a possible measure of hope, as it may be possible eventually to produce an attenuated living vaccine which, by inducing a mild attack of the disease, may evoke a sufficient degree of active immunity to tide susceptible animals over a strangles season. Concurrently with this experimental work, much research has been done in the typing of streptococcal strains isolated from individual cases of the disease.

(*m*) *Equine Abortion.*

This disease is commonly enzootic in horse-breeding areas where the problem is one of such importance as to have occasioned a great volume of intensive research. It has been established for many years that the prevailing cause of equine abortion is an organism of the Salmonella group, *S. abortus equi*. Evidence is not lacking, however, to show that other organisms, either primarily or secondarily, play an important part in the infection of the equine genital tract, tending to abortion. Among these, streptococci and strains of *B. coli* have been isolated from fœtal specimens, with sufficient frequency to indicate their pathogenic rôle in the disease.

Research has, naturally, been directed chiefly towards the control of abortion due to the prevalent type of organism and, in recent years, considerable success has been attained by the use of a polyvalent anti-abortion vaccine prepared at the Institute from strains isolated from clinical cases.

The problem of equine abortion is related to that of sterility, and in this phase of the disease, research has been synchronized.

It is becoming increasingly apparent that, apart from specific infections, nutritional factors, including vitamin deficiencies, exert a determining influence in infections of the genital tract and the help of the bio-chemist has been invoked in the solving of the various phases of the disease syndrome eventuating in abortion.

(*n*) *Equine Lymphangitis.*

Inflammation of the subcutaneous lymph vessels leading to nodular lesions and abscesses receives much attention in army veterinary work, and the differential diagnosis of lymphangitis is considered important. As a result of recent experience in several stations in Northern and Central India, where multiple or sporadic cases of lymphangitis, clinically indistinguishable from infections due to *Cryptococcus farciminosus*, have occurred among cavalry horses, two hitherto unrecognized forms, viz., a staphylococcal and a streptococcal, have been added to the list of the known forms. The former was the more frequent of the two, and developed as an acute disease and responded readily to ordinary treatment. No immunity resulted from attacks. The streptococcal form was more persistent and showed no tendency to spontaneous healing, and resembled cases of spurious or irregular strangles. An unusual case of intestinal infection due to *Cryptococcus farciminosus* in a mule was encountered.

(*o*) *Poultry Diseases.*

These diseases are daily demanding more attention. They have been the subject of investigation for many years in India, and the existence of certain diseases is now well established. Research has been carried to the logical conclusion of providing biological products to protect poultry against the ravages of some of them. For others, including the dreaded Doyle's or Ranikhet disease, no satisfactory product has yet been devised.

Fowl cholera (*Avian pasteurellosis*) is probably the most fatal of all bird diseases when originating spontaneously in a flock. Research has shown that an attenuated vaccine and serum, prepared from suitably selected strains of the organism, are efficacious in protecting birds against the disease and in controlling outbreaks when combined with appropriate hygienic measures.

Salmonella infection of chickens—the bane of poultry farmers in Western countries—has, as a result of investigation, been found to be practically non-existent. On only one occasion has an organism resembling *S. anatum* been recorded from diseased chicks that died soon after hatching. Outbreaks of disease due to *S. pullorum* have never been encountered in India. On only one occasion, and that a sporadic, isolated outbreak in the Kumaon

Hills, has authentic fowl typhoid, due to *S. gallinarum*, been described in India. An experimental vaccine failed to confer any immunity upon birds exposed to this infection, either by natural or artificial means.

Research records indicate that avian tuberculosis is an uncommon disease in India. A few isolated outbreaks of apoplectiform septicæmia, due to an encapsulated streptococcus, have been diagnosed. Moniliasis—a fungoid disease of chickens, affecting the alimentary tract—has been reported from Bengal.

(*p*) *Canine Diseases.*

Canine diseases, particularly the febrile conditions, are a perplexing problem to the dog owner in India. The chief difficulty lies in accurate diagnosis; the similarity of symptoms or the lack of laboratory diagnostic facilities confusing the issue. Where accurate diagnosis has been attempted, it has been found that the bacteriology of canine fever discloses a variety of infections to which it was not hitherto considered the dog was subject. For example, it has been proved during recent years that many cases tentatively diagnosed as Tick fever—the bête noire of canine flesh in India—were actually cases of a typhoid-like fever.

Considerable research has been devoted to the problem of typhoid and *Salmonella* infections in dogs in India and the outcome of this work is the general acknowledgment that organisms of the colon-typhoid group are more frequently the cause of obscure canine fevers than one was formerly led to suppose. A variety of *Pasteurella canis* has been described as a cause of canine fever annually occurring in certain kennels in the United Provinces. *B. pseudo-tuberculosis rodentium* has, within recent years, occasioned much research as another possible cause of canine fever.

III. Protozoology.

The great majority of the protozoa are free living and are found on the surface of the earth, in soil and stagnant water and they play a great part in the economy of nature. A large number live normally in the digestive tract of animals especially herbivora, exerting no harmful effects, rather in some cases rendering aid to the host in the process of digestion. In comparatively few instances, however, the parasitism by certain of these protozoa has a harmful effect on the host, and thus some of the most widespread diseases of both man and animals, such as Malaria, Sleeping sickness, Redwater, East-coast Fever and Surra are caused by them.

All domesticated animals are susceptible to infection by protozoal parasites and with our increasing knowledge of the number of host subjects and diversity of parasites with which each host may become affected, the subject becomes of even greater

importance to Veterinary Research workers than it is to the practitioners of human medicine. The reason why these protozoal diseases are of far greater importance in tropical countries is not because the animals themselves are more susceptible to the effects of infection in these countries, but because of the mode of transmission in the great majority of these diseases. Transmission of infection is brought about not by direct contact, as is the case in most of the bacterial and virus diseases, but by an intermediate host, a so-called vector, in the form of a biting fly or tick. The distribution of these diseases is, therefore, restricted to the territories in which the climatic conditions are favourable for the survival and multiplication of the vectors. In the case of such conditions as Amœbiasis and Coccidiosis, which are not infrequently encountered in small animals and fowls in India, infection is caused through ingestion of a resistant infective stage.

(a) *Surra.*

Surra is the most important of the protozoal diseases found in this country, and occurs amongst camels, horses, mules, cattle, elephants, and dogs. Camels and horses are very susceptible to it and the rate of mortality amongst them is very high. The disease occurs mainly in the Punjab, North-West Frontier Province, Sind, and Rajputana where the population of camels is high and they constitute the usual mode of rural transport. Outbreaks have been reported from all the other provinces of India with a very high rate of mortality at times, but the disease is not so widely distributed in these parts. Enzootics are now reported with increasing frequency in cattle and it is thought that these animals may act as reservoirs for the trypanosome and harbour infection for many years without manifesting any symptoms.

The disease is caused by *Trypanosoma evansi* and in India it is considered to be transmitted to susceptible hosts through the agency of some biting fly which acts as a mechanical carrier. In horses the disease has a very short duration but in camels which are well fed and not overworked, it runs a course of two to three years.

As there was no remedy known for this disease, Equine Surra was formerly scheduled under the Glanders and Farcy Act in all provinces; the affected cases were destroyed and compensation was paid to owners. Cattle, however, could not be destroyed on account of the religious sentiment of the more orthodox class of Hindus, and for this reason the attention of the earliest workers was directed to discover a suitable chemical which would bring about complete sterilization of the system of the host and so avoid destruction.

In the year 1911, the treatment of Surra with Tartar Emetic and a preparation of arsenic, or both combined, given intravenously

at certain intervals, was commenced with good results, but the most important piece of work in the treatment of Equine Surra was done by Edwards at the Muktesar Institute in the year 1925. The treatment consisted in an intravenous injection of 50 c.c. of a 10 per cent solution of 'Bayer 205', a proprietory preparation newly put on the market, per 1,000 lb. body weight, and intrathecally 20 c.c. of a 0·1 per cent solution of the same per 1,000 lb. body weight, repeated a fortnight later. This method of treatment proved very efficacious and was recommended for adoption in the field.

In the year 1929-30, in the Punjab, three modifications of this method of treatment of Surra were tried with a view to reduce the time taken and the number of injections required. Though the results obtained were satisfactory, it was considered premature by the authorities to say anything with regard to their effectiveness as the experiments were conducted on artificial cases only. The Muktesar Institute, however, after carrying out a short experiment in 1933, found that an intravenous injection of Bayer 205, at the rate of 5 grams per 1,000 lb. body weight, gave the same results as the intravenous-intrathecal method of treatment in artificially infected cases of Surra. This finding was of importance as the latter method of treatment cannot be easily adopted under field conditions.

With regard to the vectors in this condition, in the year 1927-28, as a result of some transmission experiments in the Punjab, it was claimed that *Ornithodorus crossi* is capable of spreading the disease up to 622 days after it has been fed on an infected animal and can survive for 739 days without food. But the results of a series of similar experiments carried out in the year 1935 at the Muktesar Institute with the object of confirming this report proved entirely negative.

Regarding the identity of the cattle parasite, Sterling observed in 1921 that the trypanosome found in the blood of a bullock which died in the Central Provinces in India was quite unlike *T. evansi*, and stated that it had the characters of *T. congolense.* No other worker has found this trypanosome in cattle in India. Other workers have studied the morphological and biological features of the trypanosomes affecting cattle in India and have come to the conclusion that they are identical with *T. evansi*.

Extensive observations on the curative treatment of Surra in bovines by means of Bayer 205 were made at the Muktesar Institute from 1934—36, and it was found that treated animals remained entirely free from infection after the initial sterilization of their blood by drug injection.

Another large trypanosome, viz., *T. theileri*, has been reported from cattle but its acquiring a pathogenic rôle has never been proved. Transmission experiments with this organism in laboratory animals have given negative results.

(*b*) *Dourine.*

Dourine was formerly rampant in several horse-breeding farms in the Punjab and United Provinces, but has been more or less stamped out by destruction of affected mares and castration of the males. Since the year 1919 no case has been reported in this country.

(*c*) *Bovine Piroplasmosis.*

The common piroplasm of cattle in India is *B. bigemina.* A large proportion of Indian cattle are natural carriers of the disease and symptoms become manifest during the course of an intercurrent disease, especially Rinderpest, and are then attended with mortality.

In 1926, Cooper at the Muktesar Laboratory carried out certain infection experiments with *B. bigemina* and thereby confirmed the work of other workers that injection of blood containing these parasites into a susceptible bovine animal set up the disease in the same manner as is done through the agency of ticks under natural conditions.

In 1935 the ineffectiveness of trypanblue as a prophylactic agent against *B. bigemina* infection in cattle was noted. This drug, even when administered in the maximum dose tolerated by the animals, failed to bring about the desired result. A series of controlled experiments was, therefore, undertaken to ascertain whether such failures were attributable (1) to a deterioration in potency of the particular brand of drug used, or (2) to the fact that a 'trypanblue fast' strain of *B. bigemina* was being dealt with in these trials. A fresh supply of trypanblue was obtained from Messrs. E. Merck, Germany, and its efficacy tested upon six artificial cases of red-water simultaneously with five others treated with the old stock. None of these animals showed sterilization of their blood. That the strain was not 'drug fast' was ruled out as a result of tests carried out upon sixteen bulls infected with a fresh untreated strain of these parasites. The use of trypanblue in the treatment of red-water has since been discontinued and has been replaced by the proprietory preparation 'Akiron R' manufactured by the Bayer Co. The minimum effective dose has been found to be 2 c.c. per 200 lb. body weight given subcutaneously or intramuscularly. With the introduction of this drug the problem of rendering serum-making bulls free from *B. bigemina* may be taken as solved.

(*d*) *Canine Piroplasmosis.*

The tick fever of dogs so prevalent in India is attributable to infection with two entirely different piroplasms, viz., *Babesia canis* and *Babesia gibsoni*, the latter appearing to be the far more important cause of the disease in India.

Most of the work on the life-history of these parasites has been done in Madras, and in 1926 Rao noted the occurrence of a parasite identical with *B. gibsoni* of dogs in the blood of a jackal, and therefore tried transmission experiments with *Hæmaphysalis bispinosa*, a tick commonly found on jackals, but with indefinite results. On the other hand, transmission experiments at Muktesar with *B. gibsoni*, using the common dog tick, *R. sanguineus*, gave a positive result in one case. Shortt has recently worked out the life-history and morphology of *Babesia canis* and given a consecutive description of the stages of the parasite from the time it is ingested by nymphs of *Rhipicephalus sanguineus*, the known vector in this condition, up to its transmission by the adult, during the act of feeding, to a fresh host.

(*e*) *Equine Piroplasmosis.*

Piroplasmosis has also been found to occur in horses in India. *Babesia caballi*, the larger parasite which occurs in the red blood corpuscles in characteristic pairs, causes fever, hæmoglobinuria, and anæmia. This is, however, amenable to treatment with trypanblue. *Babesia (Nuttalia) equi* is a smaller parasite which produces biliary fever in horses and causes jaundice. Quinine hydrobromide has so far given satisfactory results in keeping down the diseased condition but a specific for this ailment has yet to be found.

(*f*) *Other Piroplasmoses.*

Babesia motasi in the blood of a sheep has been recorded in the Mysore State. The experiments to transmit the parasites to goats gave a negative result.

In the course of routine examination of blood smears at the Muktesar Laboratory *Babesia sergenti* was found in the blood of a goat. It was shown to be inoculable to other goats and produced symptoms of piroplasmosis. *Piroplasma taylori* was described as a new species of piroplasm from the goat, but the resemblance of this parasite to *Theileria hirci* has since been pointed out.

(*g*) *Theileriasis.*

The common form of *Theileria* encountered in cattle in this country is *Theileria mutans*, but usually this is regarded as a harmless and almost ubiquitous parasite.

According to the report of the Civil Veterinary Department of the Central Provinces of India, the presence of *T. mutans*, previously confused with the smaller form of *B. bigemina*, was microscopically confirmed in the year 1915, and in the following year some blood films from cattle of the Central Provinces were sent to Sir Arnold

Theiler who confirmed the presence of *Theileria mutans* and *Anaplasma marginale* in the specimens.

In the year 1929, at the Imperial Veterinary Research Institute an investigation of much importance was commenced upon acute Theileriasis affecting Holstein stud bulls imported by the Military Farms Department into India from South Africa. These animals had been submitted to blood inoculations in South Africa before export with the object of immunizing them against African 'piroplasmosis' caused by infection with *B. bigemina* and *Theileria mutans.* The fact that a large number of the animals became affected with a *Theileria* shortly after their arrival in this country, in spite of inoculation carried out in South Africa, indicated that the *Theileria* parasites of India differ markedly in their pathogenicity from the *Theileria* of South Africa. The bulls were probably subjected to heavy tick infestation very shortly after their arrival in India and also during transit from Bombay where they were disembarked to different farms in the country.

The first published record of the occurrence of acute Theileriasis in India is contained in the annual report of the Muktesar Institute for the year 1934. In the previous year an extensive series of observations was carried out upon a virulent form of this disease found affecting the local hill bulls. A strain of the 'virus' was isolated from a fatal case of natural Theileriasis and has since been kept alive by passaging through susceptible hill bulls.

The question of the specific identity of the *Theileria* parasites occurring in India has till now been a matter of considerable difficulty and the views extant on the subject would appear to be that the parasite concerned is perhaps a form intermediate in virulence between *T. mutans* and *T. parva,* the cause of East Coast Fever of cattle in South Africa. In the course of the investigations on Theileriasis in cattle at Muktesar in 1933, it was stated that of the four well-known species of cattle *Theileria* (*T. parva, T. dispar, T. annulata* and *T. mutans*), *T. annulata* would appear to possess the closest affinity to the parasite causing the acute condition in hill bulls at Muktesar, but they differ in certain essential characteristics, the most noticeable of which are (*a*) the decidedly lower mortality rate in *T. annulata* infections (5 to 20 per cent) as against the mortality rate of 82 per cent obtained with the Muktesar parasite, and (*b*) the somewhat lesser percentage of round forms in *T. annulata* infection (70 to 80 per cent) than is the case in the Muktesar parasite (80 to 90 per cent). A series of preliminary experiments were carried out upon the viability of the 'virus' and it was found that when stored under sterile precautions in the refrigerator, it completely lost its infectivity within six days. It may be pointed out here that *Theileria* have not been recorded from indigenous cattle excepting those from the Kumaon hills.

A fairly large number of drugs such as Plasmoquine, Piroblue, Todorit, Trypaflavine, Antimosan, S.U.P. 36 and Sulfarsenol,

have been tried on account of their known parasiticidal value, but the results have not been encouraging. Since drug treatment has failed to give the desired result, the attention of the Muktesar Institute has recently been directed towards the possibility of producing an anti-Theileriasis serum. Extensive experiments on these lines have been undertaken and the results so far achieved are fairly encouraging.

The transmitting agents of this organism in India are not known but it is assumed that ticks play the rôle of the intermediate host. Research work on these lines along with the study of the exact identity of the parasite have now been taken up by the Muktesar Institute.

In 1925 *Theileria ovis* along with 'Koch's blue bodies' was seen at the Muktesar Laboratory in a blood smear from a lamb received from Madras.

(*h*) *Anaplasmosis.*

The presence of Anaplasmata in the blood of cattle, sheep, horses, dogs, and some wild animals was reported in the year 1914-15 in the Central Provinces and in the following year the finding was confirmed as regards cattle by Sir Arnold Theiler. Disease in cattle caused by these organisms has not been recorded in this country although it is a well-known morbid entity in certain other parts of the world, notably in Africa.

The report of the Muktesar Institute for the year 1932 states that Anaplasmata are now and then encountered in the blood of hill bulls but sub-inoculation in healthy bulls gave a negative result, probably for the reason that the inoculated animals were carriers. Attempts to reproduce the disease in some small laboratory animals by inoculation of blood showing large number of these bodies obtained from an imported Ayrshire bull also gave a negative result.

(*i*) *Leishmaniasis.*

This condition is manifested in dogs under two different forms, the visceral form and the cutaneous form, the parasite in either case being morphologically indistinguishable from *Leishmania donovani* of human Kala-Azar.

Cases of canine cutaneous Leishmaniasis have been recorded from the N.-W.F. Province and the United Provinces and a single case of cutaneous Leishmaniasis in a bullock has also been recorded from Assam.

(*j*) *Coccidiosis.*

Coccidia of different species affect different animals. In cattle, rabbits and fowls infection with these parasites causes grave outbreaks of disease. The infection in India amongst cattle, which is

due to *Eimeria zurni*, assumes a good deal of significance; not so much as a pure infection capable of producing disease by itself but from the fact that it can be resuscitated from its ordinary dormant state by intercurrent affection, so as to set up severe or even fatal complications.

Cooper discovered a coccidium in an ox in Assam which he believed to be a new species, belonging to the genus *Isospora*, but this needs confirmation. The occurrence of *Eimeria smithi* in a hill bull has been noted at the Muktesar Institute. This is the first record of the occurrence of this species in Indian cattle.

(*k*) *Amœbiasis.*

The first spontaneous outbreak of amœbic dysentery among hounds was described from Madras in 1916. Again in 1931 a similar outbreak was recorded among the hounds of the Bangalore hunt. The amœba in question is said to present all the morphological characters of *E. histolytica*. The potential source of infection, it is suggested, is the human being. Cysts were never seen during the course of examination of fæces and as vegetative forms are incapable of producing infection it follows that infection from hound to hound is impossible.

(*l*) *Buffalo-Malaria.*

Sheather in 1919 described *Plasmodium bubalis* from a male buffalo which was obtained at the Muktesar Institute from the plains (Bareilly) to serve as a serum maker. Since that time this parasite has been seen many times at this Institute but experiments to maintain a strain by injecting blood containing the parasite into other buffaloes have always been met with a negative result. This parasite has also been seen once in Madras.

(*m*) *Spirochætosis.*

Spirochætes have been recorded from various animals from time to time. A few years ago the hounds of the Madras Hunt Club were believed to have died of *Leptospira icterohæmorrhagiæ* infection. *Spirochæta recurrentis* was once isolated from a bovine animal in Madras but no further report has been made of this parasite from India.

Considerable losses have occurred in the poultry of this country on account of infection with *Treponema anserinum*. The disease is transmitted through the agency of the tick *Argas persicus*. In cases where the disease is diagnosed, treatment with intramuscular injections of Atoxyl is carried out with successful results.

(*n*) *Miscellaneous.*

The occurrence of *Hepatozoon* (*Hæmogregarina*) *canis* was noted in a dog from Cocanada. Infection is stated to be very debilitating to the animal. Schizogony has been found to occur in bone-marrow, spleen, and liver of the host. Stages of sporogony of the parasite in *R. sanguineus* have also been observed and mostly found to correspond to what was already seen and described by Christophers in 1907. This organism has also been seen at the Muktesar Institute from time to time in dogs used for maintaining a strain of *B. gibsoni*. *Globidium fusiformis* has been described from Indian cattle. A very similar organism was also encountered in the fæcal matter of a hill bull affected with dysentery at the Muktesar Institute. Nothing however is known about its pathogenicity or its distribution among Indian cattle.

IV. Entomology.

The past 25 years have witnessed a growing recognition of the importance of exploration of the dipterous and arachnid fauna of India as an essential preliminary to the formulation of working hypotheses in regard to the species of vectors likely to be involved in the transmission of certain animal diseases in this country. In the absence of a suitable organization for dealing with problems of Veterinary Entomology in India, such exploration has been largely incidental to other activities of the Veterinary Department and also to those of the Medical and Agricultural Departments and the Zoological Survey of India. A census of the arthropod pests of veterinary interest on record shows, however, that in spite of a lack of continuity of effort in the matter of carrying out systematic entomological surveys, our knowledge, at any rate of the insect pests of cattle, has substantially advanced during the period under review. Of the workers who have made notable contributions in this direction, mention must first be made of Brunetti, who published as many as three volumes dealing with Diptera, in the series of *Fauna of British India* (1912, 1920, 1923) besides a large number of miscellaneous articles scattered in the *Records of the Indian Museum*. In 1919, Brunetti published a useful review of progress in our knowledge of Oriental Diptera during the preceding two decades, the Diptera of economic importance considered therein including several species of *Simulium* and the well-known European dung fly, *Scatophaga stercoraria*, which had not previously been recorded from the East.

The most notable contributions on the systematic side of Veterinary Entomology in India, however, have been those of Patton, who, in collaboration with Cragg, brought out, in 1913, a comprehensive volume embodying a considerable amount of available information on the arthropod pests of domestic animals

in this country, besides original observations upon their life-history and bionomics, and, although largely out of date, it continues even to this day to be the vade-mecum of both the Veterinary and Medical Entomologist in India. Patton and Cragg in 1913 mentioned the occurrence of the so-called hæmatophagous Muscids (e.g., *Musca pattoni*, *M. gibsoni*, *M. bezzi*), which have the habit of travelling directly from an infected wound to an uninfected one and are therefore a potential source for the spread of infection. In the same year, they published a paper advancing reasons for the abolition of the genus *Pristirhynchomyia* previously erected by Brunetti and for sinking it into the genus *Philœmatomyia*, which itself has now been sunk into the large genus *Musca*. Patton's own distinctive contribution in the field of systematic Entomology, however, has been upon the oriental species of the genus *Musca*, and by clearing the synonymy of this most difficult group he has earned the lasting gratitude of all students of Indian dipterology. Patton was also the earliest to record the occurrence in India of the Anthomyid fly, *Passeromyia heterochœta*, which is a blood-sucker in the larval stage.

The systematic side of Veterinary Entomology in India has also found a zealous worker in Senior-White, who brought out two useful catalogues dealing with the Culicidæ and Tabanidæ of the Indian Region, besides a memoir containing descriptions of many new species of Diptera, including the Tabanidæ and Simulidæ occurring in the Khasia Hills in Assam. In 1926, Senior-White published a useful revision of the sub-family Calliphorinæ which has now been raised by some authors to the rank of a family.

Of the other workers in this field, mention may be made of Puri (1932—35), who, although a recent worker in this field, has described a large number of new species of the genus *Simulium* occurring in the Indian Region ; and Sharif (1924, 1928), who has made outstanding contributions upon the Indian species of the family Ixodidæ and the order Siphonaptera. In connection with the subject of Ticks, an event of considerable interest is the discovery of the occurrence in India of *Ornithodorus megnini* or the so-called Spinose Ear Tick, for so far this species has only been recorded as a serious pest of domestic animals from certain parts of America and South Africa.

During the period under review, a number of interesting observations have been made upon the species of Warble flies occurring in India. Thus, Patton has shown that the common warble-fly of cattle in this country is *Hypoderma lineatum* and not *H. bovis*, as had been previously supposed, and that both cattle and goats in the Punjab are susceptible to attacks by another species of warble-fly designated by him as *H. crossi*, the occurrence of which has also been recorded from Baluchistan. The subject of warble-dies has now assumed a position of paramount importance, in view of the damage caused by them to hides and skins in this

country, and a systematic investigation upon these pests is being undertaken at Muktesar under a grant made by the Imperial Council of Agricultural Research.

Reference may also be made here to the occurrence in India of *Lucilia sericata* and *Chrysomyia rufifacies*, as recorded by Sinton and Holdaway respectively, for these two species belong to the formidable group of sheep Maggot Flies of Australia and must, therefore, be regarded as a source of potential danger to the sheep-breeding industry in this country.

Advances in the fields of life-history and bionomics have been made mostly in connection with the Tabanidæ and the myiasis-producing flies. Isaac carried out a series of detailed studies upon the life-history of some of the common species of Tabanids occurring at Pusa and in the course of these he made the interesting observation that authentic females of *Tabanus crassus* Wlk., raised from his rearings, agreed with *T. sanguineus* Wlk., of which only the females were known. Both these species, however, have now become synonyms of *T. rufiventris* Fabricius, on grounds of priority.

Our knowledge of the life-history of the myiasis-producing flies in India is largely due to Patton, who has studied the habits of several species of these flies belonging to the genera *Calliphora*, *Chrysomyia* and *Lucilia*. These studies have revealed the interesting fact that by far the commonest species of myiasis-producing fly in India is *Chrysomyia bezziana* and that it breeds only in living tissues, as opposed to carrion, which constitutes the normal habitat of the majority of the members of this group.

The life-history of the Arachnida has received little attention in this country, the only noteworthy contributions in this connection being Sharif's bulletin on the widely prevalent tick *Hyalomma œgyptiana* and an article by Timoney on the sarcoptic mange mite of the buffalo.

In regard to Insect Physiology, as applied to Veterinary Entomology in India, only a beginning may be said to have been made. In a paper published in 1915, Sen described a new apparatus for measuring the respiratory exchanges in the Culicidæ and showed that the oxygen-hunger in the case of the larva of *Culex micro-annulatus* was much greater than in the case of the pupa. In two other contributions he produced evidence to show that in the Culicidæ, a meal of blood was not essential for the maturation of the ova and that the act of feeding, as distinguished from biting, was not governed by a thermal stimulus.

Recent advances in our knowledge of the morphology of the biting flies of India are largely due to Cragg, whose contributions in this field have been as extensive as they have been varied. His earlier papers, which appeared during the years 1912-13, dealt with the mouth-parts of various species of blood-sucking Muscidæ and orthorrhapic flies and also with the structure of the Tabanid fly *Hœmatopota pluvialis*. In 1918, Cragg described the mor-

phology of the testaceous Calliphorid *Bengalia jejuna*, a species of considerable interest in view of its close relationship to *Auchmeromyia luteola*, the so-called Congo Floor Maggot, which is a bloodsucker in the larval stage.

Recent morphological studies in the domain of Veterinary Entomology in India have, however, largely centred round the question of the structure of the mouth-parts of arthropods. Thus, Senior-White in the course of his studies upon the possibility of the eye-fly *Siphunculina funicola* being involved in the transmission of *Frambœsia tropica*, found that the mouth-parts of this insect were adopted for scarifying and not for biting, as had been previously believed to be the case. Mukherji described the morphology of the mouth-parts of a new species of *Culicoides* (*C. clavipalpis*), while Sen discussed the mechanism of the working of the labium of the Tabanid fly *Corizoneura longirostris*. The last-named author in 1935 also reported the discovery of an undescribed organ in the mouth-parts of ticks and discussed its homology with the hypopharynx of blood-sucking diptera.

Of the advances made in the field of technique mention may be made of a method elaborated by Napier in 1930 for the artificial feeding of sand-flies, the method consisting in the use of an apparatus with wooden vices and cork balls for securing the specimens. For feeding ticks on domestic animals, Sen, in 1933, described a special cup, which he fixed to the body of the host by means of the adhesive, Chatterton's compound, and experience has shown that this method ensures the recovery of every single tick on the completion of its feed.

An examination of the records of the activities relating to the transmission of disease during the past 25 years reveals the interesting fact that the bulk of these activities has been directed to a search for the vectors of Surra (*Trypanosoma evansi* infection) affecting, in particular, equines and cattle in this country. Investigation in this connection was initiated as far back as the year 1901, when Rogers tested the possibility of horse flies being involved in the transmission of the disease, and it is being actively continued to this day. Under laboratory conditions, the infection has proved capable of being mechanically transmitted, by the so-called interrupted method of feeding, through the agency of various species of Tabanidæ, notably *Tabanus rubidus*, *T. striatus*, *T. nemocallosus*, *T. macer* and *T. Virgo*. In 1921 Cross and Patel succeeded in transmitting the infection through the agency of the tick *Ornithodorus papillipes*, and they postulated the occurrence of a cyclical development of the surra parasite within the tissues of this invertebrate host, in view of the fact that the latter did not prove infective for healthy animals until after the expiry of at least 17 days after the date of its infective feed. Cross and Patel's experiments were repeated at Liverpool by Yorke and Macfie and also by Sen at Muktesar, but the results were negative.

The question of the vectors of rinderpest has also received some attention during the period, but the results have been for the most part of a negative order. Thus, Sen carried out an extensive series of experiments to test the possibility of this condition being transmitted by *Aedes(Stegomyia)albopictus*, *Musca domestica* and the louse *Linognathus vituli*, and positive results were obtained only in those instances where crushed bodies of infected *M. domestica* were inserted into pockets made under the skin of susceptible bulls or when saline suspensions of such bodies were injected intravenously. Bhatia, however, in 1935 succeeded in transmitting the disease in one out of four experiments carried out with *Tabanus orientis*.

In the domain of canine diseases, Rao demonstrated the occurrence of sporozoites of *Hæmogregarina canis* in the tick *Rhipicephalus sanguineus* and he also showed that the development of *Filaria recondita* took place in the mosquito *Culex fatigans*, this being contrary to the views of Grassi and Calendruccio who claimed to have encountered the embryos in certain species of fleas and also in *R. sanguineus*. The condition that has received the largest amount of attention, however, in relation to the question of vectors is the so-called tick fever in dogs, particularly the fever due to *Babesia gibsoni*. In regard to this, Rao, in South India, brought forward some evidence to show that the infection was in all probability conveyed by *Hæmophysalis bispinosa*, while Sen, working at Muktesar, obtained positive results with *R. sanguineus*, but both these observations await confirmation.

V. Helminthology.

For a long time stock owners were in all good faith inclined to question the importance of the parasitic worms and deny that they do any special damage. They often attributed the losses due to worms to other causes, as the common symptoms of helminthiasis are not always sufficiently spectacular to attract immediate attention or are masked by super-imposed bacterial infection. In recent years, however, there has been a gradual realization that in a tropical country like India helminthiasis is a most serious menace to the health of the domestic animals.

Credit for the earlier work in Veterinary Helminthology in India is due mostly to a few enthusiastic officers of the Veterinary and Medical services who made valuable but spasmodic contributions to our knowledge of the helminth parasites of Indian hosts. In recent years, however, more interest has been aroused in the study of helminthology following the discovery of certain helminths as the causative agents of several diseases of domesticated animals, which had baffled solution for a long time, and the science has now been placed on a better basis at the Muktesar Institute and

attention is also being paid to it at provincial Veterinary Laboratories and at some Universities.

Veterinary helminthology aims at the conservation of animal health, by attempting the control of the parasitic worms, but, as has been pointed out by Leuckart, without a detailed knowledge of the salient features of the taxonomy, organization and life-histories of the different worms it is impossible to determine the nature and extent of damage which they do or to devise means to check their infection. The elaboration of a system of accurate identification and classification is essential to obtaining control over the various worms, and neglect of this will lead workers on the treatment and prevention of helminthiasis into blind alleys and result in loss of time, money and energy. During the period under review a large number of helminths have been described from Indian domesticated animals. Most of them have been brought together in a valuable monograph 'Helminth Parasites of the Domesticated Animals in India', published by Bhalerao in 1934. Although the work is mostly a compilation of the published papers on Indian forms it provides a much needed, ready reference book, but since its publication a number of new worms have been added to the list and the total number of helminth parasites which have been described during the last 25 years from domestic animals in India is now too numerous to be mentioned here. Special reference should, however, be made to the round worm, *Mecistocirrus digitatus*, first recorded by Sheather at Muktesar in 1917, which is a common cause of parasitic gastritis in cattle throughout India resulting in much economic loss.

Parasitic worms or helminths form an economic and not a natural grouping. They are referable to two important phyla which are related by habit only. They are divisible into four main groups, i.e., flukes, tapeworms, roundworms, and thorny-headed worms. The last mentioned group has received little attention in India. Though a thorough knowledge of the life-history of a parasite is necessary in devising means to check its infection the life-histories of very few helminths in India have so far been worked out. Liston and Soparkar, in 1917, carried out extensive studies on the life-history of the cattle blood fluke, *Schistosoma spindalis*. They discovered that the snails of the species *Indoplanorbis exustus* and *Lymnœa acuminata* serve as the intermediate hosts. Anant Narayan Rao, in 1933, worked out the life-history of another important parasite *Schistosoma nasalis*, and showed that the snails involved in its life-cycle are *Indoplanorbis exustus* and *Lymnœa luteola*. The same worker established the life-cycle of *Filaria recondita*, now known as *Dipetalonema reconditum*, a parasite of dogs, in 1923. The intermediate host of this round worm is *Culex fatigans*. Bhalerao, in 1932, showed that snails of the species *Lymnœa acuminata* act as the intermediate host of *Fasciola gigantica* in the Kumaon hills. Srivastava in 1936 established the life-cycle

of a common tapeworm of Indian dogs and cats—*Mesocestoides lineatus.* He found that non-poisonous snakes, lizards and wild rats serve as the intermediate hosts of this tapeworm.

While adult Amphistomes are to all intents and purposes non-pathogenic they are highly pathogenic in their immature stages, which are passed in the intestine, specially the duodenum. Recently the life-history of *Cotylophoron cotylophorum* has been elucidated at Muktesar and it has been shown that a biological control to check infection is available. It has been proved experimentally that when the snails, *Indoplanorbis exustus,* which serve as the intermediate host, are infected with an aquatic oligochæte, *Chætogaster limnaei*, they cannot be infected with trematode larvæ ; while the same snails when free from the oligochæte readily yield to miracidial infection. In recent years evidence has been forthcoming to show that the disease of sheep and goats, known as *Gillar* or *Pitto* in the Punjab and Sind, is caused by immature amphistomes, and the same condition has been reported from other provinces. The life-histories of two other amphistomes, *Paramphistomum cervi* and *Fischoederius elongatus*, were worked out by Anant Narayan Rao in 1931.

Bovine Nasal Granuloma

The problem of the control of helminthic infection has now assumed a position of paramount importance in veterinary science in India, in view of the fact that several previously obscure diseases of domesticated animals have in recent years been proved to be of helminthic origin. The most important of such diseases is Bovine Nasal Granuloma or the snoring disease of cattle. It is a peculiar chronic disease of the nostrils of cattle which affects large numbers of animals in India and causes considerable loss to cultivators. Bovine nasal granuloma can be easily differentiated by its naked-eye appearance and the specific microscopic features from another separate and distinct affection of the nose of cattle and horses, namely Rhinosporidiosis, described by Krishnamurti in 1927. Datta, in 1932, was the first to record certain definite findings in support of the view that bovine nasal granuloma is the clinical manifestation of a Schistosomiasis, where the worm seeks out the nose for the deposition of its eggs. With regard to the identity of the parasite, close morphological and life-history studies have been carried out in several places and it is now generally held that this represents a new species, which has been named *Schistosoma*

Equine Hepatic Cirrhosis

The elucidation of the cause of a persistent debility of equines in India had baffled the attempts of workers for a long time. The etiology of this peculiar form of nodulated hepatic cirrhosis, associated with intractable debility, of equines was largely obscure till Datta in 1933 showed it to be the clinical manifestations of a Schistosomiasis. The parasite responsible for producing this condition is

Schistosoma indicum Montgomery, 1906. The predilection seat for the deposition of ova is the distal portions of the intestinal tract, particularly the large colon, rectum and also the liver.

Bursati

Another important disease of equines which has recently been confirmed as being of helminthic origin in India is what is commonly known as 'Bursati'. The history of this disease of equines in India dates back for more than 100 years. It is a chronic inflammatory disease of the skin and subcutaneous tissue of equines. Till recently two views were held in regard to its etiology: (1) that it is of mycotic origin, and (ii) that the disease is caused by helminth parasites deposited in pre-existing sores by flies. Datta, in 1933, adduced definite evidence to show that this condition is a habronemic granuloma due most probably to *Habronema muscæ*, involving the skin and the internal organs such as the lungs.

Khoojlee

Lichen tropicus or 'Khoojlee' in horses in India is another disease the etiology of which has been under study at Muktesar. In the past the disease was ascribed to a number of factors such as dietary, non-hygienic, renal or hepatic disorders, etc. and specific agents like lice and fungus, etc. It has now been demonstrated that microfilariæ are invariably present in the sections of the affected tissue though they have never been observed in the blood of the affected animal. The habitat and the identity of the adult worm are not yet definitely known. The recent finding of *Onchocerca cervicalis* in the ligamentum nuchæ of horses suffering from *Lichen tropicus* is, however, of interest.

Hump sore

Amongst the chronic diseases of the bovine skin in India, hump sore is one that has for many years baffled the attempts of scientists to elucidate its cause, and evolve a satisfactory method of treatment. The disease appears in the form of a sore generally localized in or about the region of the hump; rarely the lesions may be situated at the yoke place, flat of neck or over the region in front of the anterior margin of the scapula. The disease does not cause any acute systemic disturbance in the animal though the condition at times assumes very distressing features owing to the continuous attacks of flies. Pande worked out the etiology of this condition in Assam in 1935. Definite evidence has been brought forward to show that it is a filarial disease. The microfilariæ as well as the adults have been obtained from cases of hump sore. The adult parasite has been described as a new species of *Stephanofilaria*—*S. assamensis*, n.sp.

Verminous pneumonia in domesticated animals is one of the most outstanding diseases for which no satisfactory method of treatment or prevention is so far known. In addition to the pneumonia caused by the migrating larvæ of certain helminths, pulmonary symptoms may be caused by worms which have their

final habitat in the lungs. The most important addition in recent years to the list of such worms has been the discovery of *Varestrongylus pneumonicus* at Muktesar in the lungs of sheep and goats.

The helminth parasites of poultry in India have not received the attention which their importance warrants. Our knowledge of the worms of poultry is still very meagre as is evident from the recent discovery of a number of highly important forms, such as a representative of the genus *Prosthogonimus—P. indicus*, n.sp., in the oviduct of fowls. This genus is considered by European workers to be the most pathogenic trematode group affecting poultry.

The occurrence of cutaneous bleeding or 'blood boils' has been shown to occur in different species of animals in several provinces. The parasite appears to be *Parafilaria multipapillosa*. Several species of *Thelazia* on the external surface of the eyes of animals have been recorded and the invasion of the aqueous humour of the eye of equine subjects by the so-called *Filaria oculi* (*Setaria equina*) is a common occurrence.

Recently, however, a separate and more serious condition affecting horses in certain north Indian stud farms, has been proved by researches at Muktesar to be due to a species of microfilaria, but the adult parasite still remains undiscovered.

VI. Animal Breeding and Genetics.

It is now recognized that the breeding of domesticated animals is a science, knowledge of which can act as a safe guide to all breeders capable of following certain laws of selection and mating on the one hand and scientific feeding on the other. Both Agricultural and Veterinary Departments are now increasingly engaged in this work as they recognize that, the more important contagious diseases having been brought under control, the most important obstacle in the way of breeding and rearing good animals in India has now been removed.

Cattle breeding

In India cattle and agriculture are inter-dependent, and the improvement of the one means the improvement of the other. Although India holds first place among countries of the world for livestock wealth and vast potential resources, yet as far as quality is concerned, she has nothing to be proud of. Previous to the period covered by this review very little attention was paid to cattle breeding, but during the last 25 years Government have taken active steps to help the cultivators to rear better stock. The shrinkage of pasture lands and the reclamation of desert tracts under irrigation have both materially hastened the deterioration of cattle, and it is only now that the Indian Agriculturist has begun to realize that it is better to keep a few good cattle than a lot of half starved scrub animals, and also that the best way to improve his stock is to use good breeding bulls. Nevertheless, concerted effort is still largely lacking, and far too many

scrub bulls remain in use resulting in the cattle population being of a very mixed type. Religious sentiment also interferes with a slaughter policy, and there is still considerable prejudice against early castration, as lowering the working value of an animal. In dealing with all cattle questions, one is faced with the fact that the cow is only regarded as the mother of the draught bullock, and her other functions count for little. The buffalo is the milch animal of the village, and the bullock the supreme transport agency of India.

Cross-breeding

Since 1907, the policy of importing Ayrshire and Friesian bulls has been adopted by the Military Dairy and a few Civil Farms. The first crosses got by these bulls were mostly markedly superior to their dams, but rapid deterioration was noted in the second, third and subsequent crosses, and attempts to cross half-bred & half-bred resulted in too large a percentage of poor stock. These disappointing results caused the Military Dairy Farms to stop the importation of Ayrshire bulls after 1924, and importations were limited to Friesian bulls.

The progeny of these Friesian bulls did not show the same degree of deterioration as those from the Ayrshire. The third cross cow (7/8 Friesian) has been found to be a commercial cow in most cases, though it is very susceptible to diseases and suffers severely from Foot and Mouth disease. However, it has been found that if the third cross is made a 'back-cross', i.e., an Indian bull is used, there is a remarkable regeneration.

Experience gained by these experiments has shown that it is possible to establish a high yielding herd in a short time by crossing Indian cattle with European sires. This method is only a short cut and is not to be recommended on account of its limitations, as it is definitely unsuitable in the long run. For, though cross-bred cattle may be useful for dairy farms, they are certainly of no use whatsoever to the ryots and their value in relation to the permanent improvement of Indian cattle is, therefore, practically nil.

Selective Breeding

The successful development of indigenous breeds of Indian Dairy cattle has been demonstrated nowhere more clearly than in Matson's work on the Sahiwal herd of the Military Dairy Farm at Ferozepore, where in 25 years a first class milch herd has been built up fully equal to the average milch herd in a European country, and nowhere was it more clearly shown that the use of bulls carrying milk improved the herd far more rapidly than any other means; but the bulls' milch capacity must be known before hand. Under the Government of India, selection work combined with a system of line breeding is also being carried on in the Sahiwal herd at New Delhi, Tharparkar and Hariana herds at Karnal, and Sindhi and Gir herds at Bangalore.

Similar work in the provinces has shown gradual but decided

progress during the last 25 years. The Punjab authorities have steadily pursued their Hariana bull breeding and distribution policy from the Hissar Cattle Farm, which now aims at producing 1,000 breeding bulls a year, and the effect on the provincial cattle is becoming marked. Selective work is also in progress on the Dhanni breed in the north of the province and attention is being paid to the development of the Sahiwal as a milch breed through the agency of Grantee Farms.

In the United Provinces, selective work is also in progress with herds of Hissar and Sahiwal cattle, and also with two local draught breeds known as Ponwar and Kherigarh.

In the Bombay Presidency most attention has been paid to the development of the Kankrej breed as a dual purpose animal at the Chharodi Farm, but local interest in cattle breeding is also being aroused by the establishment of Pedigree Herd Books for other breeds found in the province, such as the Amrit Mahal, Khillari and Krishna Valley.

In Madras, pure herds of the Kangayam, Sindhi and Ongole breeds of cattle have been built up by selection while, in the Central Provinces, attention has been paid to the Malvi, and a local draught breed known as the Gaolao.

Dual-purpose animals

The demand in India is for a dual-purpose animal, and it is unfortunate that this idea should have found its way from countries where milk and beef, not milk and draught, are the combined qualities. This combination is obviously impossible, as a good milch cow is a slow walker and fast walking breeds so essential for draught are handicapped by milch points. Dual-purpose work is holding back improvement on both classes of breeds, and it would be better to concentrate on milk and draught points separately. The Amrit Mahal, Kangayam and Malvi working breeds cannot be compared with the Sahiwal, Sindhi and Gir breeds as milk producers and *vice versa*.

By careful selection improved types of the best cattle of each class are now available. Limited selective breeding can be utilized to improve points lacking or dormant within the type, but any attempt to go further will only result in damage to both outstanding qualities of both classes of breeds. There are a few dual-purpose breeds, however, in some Provinces. The Government Cattle Farm at Karnal breeds two types of dual-purpose animals, the Hariana and Tharparkar breeds. The Ongole breed of Madras is also a dual-purpose breed, but being heavy, consumes a large amount of food and as such is not economical for the poor cultivator. The Kankrej of Bombay is a dual-purpose breed, but it matures late, calves twice in 3 years and is difficult to manage.

Purity of Stock

In India it is very difficult to find any breed which is really pure. Indiscriminate breeding has gone on far too long. The Sahiwal breed, which is usually

regarded as the purest milch breed, is reported by Matson as capable of reproducing X from X to X only 3 times in 4, while many of the high yielding cows cannot breed true. The inheritance of characters in Indian cattle is highly complex, and the breeder will meet with many disappointments before the indigenous breeds are thoroughly purified.

Pedigree

The pedigree is merely a description and can never be taken as a basis for milch improvement, though most progress to date has been made by the use of pedigree bulls. Until a bull is proved, he is as much a factor for harm as for good in any pedigree milch herd, and the better the herd the greater the risk run by using an unproved bull. The first Sindhi bull which was furnished to the Allahabad Agricultural Institute decreased the milk production of all his daughters below their dams. After three generations of progress in a breeding farm at Surat the introduction of a bull in the fourth generation brought about a serious set back in the yield of all his daughters.

Progeny Test

Genetics teaches us that a parent can be judged by the quality of his offspring and in milch circles this is the only road to sure progress. The old method of breeding for milk by the purchase and use of a young bull of known milch pedigree for high performance at the pail is now known to be a pure gamble, and the only definite way of improving milch stock is by using a proved bull whose stock testifies his ability to transmit.

Scientific work in Animal genetics

A Sahiwal herd, bred on scientific lines, has been established at Pusa[1] for upwards of 32 years and a number of problems are under study there. In particular reference may be made to some which were commenced by Wynne Sayer in 1932. He found that the late maturity of the Sahiwal breed (the heifers did not take the bull until 2 years and 6 months, while the bulls did not serve until over 3 years) was a very great obstacle to the work of introducing proved bulls, as the average bull was well over 9 years before anything was known about his daughters. Special feeding was, therefore, introduced and bulls are now serving at one year and 7 months and heifers taking the bull at 1 year and 6 months to 1 year and 8 months. In all cases the stocks thrown are normal and as healthy as those bred from and by older cattle. The results are far reaching and should accelerate the improvement of milch breeds considerably.

Impotency and Sterility in breeding stock

The causes of the gradually increasing number of cases of impotency in bulls and sterility in cows in the Pusa Sahiwal Herd have been under investigation since 1931 and it has been found that most of these cases were due to faulty feeding pursued in the past. Some of the cases, which were not amenable to treat-

[1] Now at the Imperial Agricultural Institute, New Delhi.

ment by changed rationing, yielded to hormone treatment. Detoxicated and neutralized urine of cows eight months and over in calf was injected subcutaneously in such cases in doses of 10 c.c. for every 100 pounds body weight daily on four consecutive days, and this dose was repeated wherever necessary after three weeks. This method of treatment is claimed to have rejuvenated bulls and produced oestrum in cows. Kerr, in Bengal, also claims to have obtained satisfactory results by this hormone-therapy. A few buffaloes were injected with Prolan at Muktesar early in the lactation period with a view to produce oestrum and thus shorten the dry period. Animals so treated showed signs of oestrum and were covered subsequently.

Artificial Insemination

The importance of developing artificial insemination in farms where herd numbers are large, but the number of improved sires is limited, is obvious. In Mysore, it is intended to employ this technique as a means of obtaining more progeny from the imported Merinos, and on the Hissar Farm it is employed in connection with donkey breeding.

Castration

Castration of inferior male stock has been pushed on with vigour and castration by the Burdizzo emasculator has now become very popular. In 1911-12 the total number of castrations performed in all British India was only 3,042, while in 1934-35 the number was as high as 608,925.

Buffalo-breeding

The buffalo has always occupied a special position in India as a milk producer and for the higher percentage of butter-fat in its milk. There are over a dozen breeds of buffaloes in the country and these animals are found in a purer state than the herds of village cattle due to the absence of any religious sentiments in regard to them, which allow unwanted animals to be more easily disposed of.

Efforts are now being made by Government to encourage the keeping of well-bred male buffaloes for stud purposes, and owners show great care in the selection of the bull buffalo. In the Punjab alone, the District Boards in 1934-35 had 2,076 buffalo bulls at stud.

Goat-breeding

With the exception of a few Government and Mission breeding farms, goat-breeding is entirely in the hands of illiterate villagers. At Hissar, the nucleus of a flock of milking goats was formed in 1928 by purchases of indigenous animals, and by selecting the best milk producers an excellent herd of Jamnapari goats has been built up. These goats give as much as 8 pounds of milk a day at a low cost of maintenance. The Etah Mission Farm, U.P. has also developed two herds of Jamnapari and Barbari goats, which are proving good milk producers, with funds provided by the Imperial Council of Agricultural Research.

Sheep-breeding

It is of interest to remember that Australia built up its great sheep breeding industry by importing sheep from India and the Cape a little over a century

ago. The wool of the indigenous Indian sheep, however, is poor in quantity and coarse in quality. In many parts of India, sheep are kept by zamindars more for the sake of manure than for the sake of wool, sheep are thus looked upon as 'walking dung carts' and their entire management is left in the hands of menials or servants, who are not interested in the improvement of the breed. The introduction of Australian Merinos has proved successful in some places, e.g., at Hissar, where the cross-bred Hissar-dale sheep compare favourably with pure Merino sheep in wool production and they are hardier. Mysore also possesses a small flock of half-bred Merinos which are quite acclimatized and breeding well.

Horse-breeding

In British India, horse-breeding is almost entirely in the hands of the Army Remount Department and a few Government and private stud farms, and it is at present mainly confined to the northern provinces. Some horse-breeding is also carried out under State auspices in Kathiawar, Mysore and Hyderabad.

With a view to making India more independent of foreign markets for horses and mules, the Government of India, in 1912, sanctioned a scheme for the formation of a horse-breeding circle in northern India, and horse and mule breeding areas have been established at Shahpur, Multan, Chenab, Rawalpindi, Amritsar, Meerut, Ahmednagar and Mona. Most of the sires that are being used are English thoroughbred stallions, but some Arab stallions are bred at Ahmednagar and donkey-stallions at Mona for issue to breeders and District Boards.

Thirty years' experience of Indian horse-breeding has shown that as good horses can be bred in parts of India as in any other country. Much has been done by careful mating with English thoroughbred and Arab stallions to improve the quality of Indian horses, with the result that the Remount Department has already replaced nearly 40 per cent of the Australian stock which was previously used for military purposes by equally good Indian horses.

Equine Pregnancy diagnosis

Since the publication of the Zondek-Aschheim test for the diagnosis of human pregnancy, efforts have been directed during the last decade towards evolving similar tests which would be applicable to domestic animals. Good results have already been obtained with mare's urine and blood serum and six different biological tests have been devised. At the request of horse-breeders in this country, this work has been undertaken at Muktesar since 1931 with excellent results.

Poultry breeding

The present-day poultry of the world have been evolved from the Indian Jungle fowl, but till recently poultry breeding as a cottage industry has not received the attention that it deserves in India. The successful work in

poultry breeding carried on at Lucknow and Etah for some years past has now aroused considerable interest in the development of this valuable industry, and poultry farms have been started at Kirkee, Gurdaspur and other places. The industry is, however, severely handicapped by the ravages of contagious diseases.

VII. Animal Nutrition.

Although the problems connected with Animal Nutrition have been studied in other countries for a long time, it is only during the last few years that any attention has been paid to this subject in India. This is not surprising when we remember that even the study of human nutrition, with which the people are directly concerned, did not until recently receive much consideration. One of the principal features of the latest developments in scientific research in India, however, is the better provision made for a study of nutritional problems both of animals and human beings and results already obtained point to a close correlation between deficiency in the feeding stuffs and the general condition of malnutrition observed throughout the country. The importance of studying purely animal nutrition problems will be apparent when we remember that the agricultural prosperity of this country depends to a great extent on the better utilization of our live-stock, both for milk production as well as for draught purposes.

The first organized attempt to study animal nutrition was made in 1921 by the creation of a Physiological Chemist's Section in the Imperial Agricultural Research Institute, Pusa, and after a period of two years, this Section was transferred to Bangalore where it formed one of the two wings of the Imperial Institute of Animal Husbandry and Dairying. Almost simultaneously, work on this subject was begun at the Chemical Research Laboratories of the Agricultural College, Lyallpur. In 1926, work of a similar nature was commenced at the Agricultural Research Institute at Coimbatore and quite recently, with funds provided by the Imperial Council of Agricultural Research, Animal Nutrition work has been started in the agricultural laboratories at Dacca.

The above laboratories have confined their attention mainly to the question of feed in relation to the productive capacity of animals and important results on this subject have been obtained. On the disease side, the question of malnutrition in relation to the health of animals has been studied at the Imperial Veterinary Research Institute, Muktesar, from 1930 in close collaboration with the Military Department, as also with various provincial workers, and valuable information has been obtained as to the extent of nutritional disorders of animals in different parts of the country and the method of their prevention.

From the brief statement made above, it will be observed that, properly speaking, scientific research in Animal Nutrition has been in progress in India for the last 15 years only. Within this short

time, however, results of considerable importance have been obtained and the problems connected with the nutrition of farm stock are now better understood. The experimental work carried out has been mainly of two types. In the first, a survey has been carried out of the different kinds of foodstuffs available in the country, their area of cultivation, soil conditions, the chemical composition of the crops, their digestibility coefficients and nutritive values. These have in a way involved the second type of work, namely, feeding experiments, the testing of feeding standards, feed in relation to milk production, growth and reproduction, mineral and vitamin requirements and malnutrition in relation to disease.

Coarse fodders

To give some details of this work, it may be stated that Indian coarse fodders have received a good deal of attention in most of the laboratories, because roughages form the bulk of the ration of animals in this country, and malnutrition and nutritional disorders almost invariably arise from deficiencies in the roughages. Feeding trials on various typical fodders have shown that very great variations in quality exist in fodders of the different parts of the country, the nutritive values ranging from 14 to 60 S.E. per 100 lb. of the dry substance. The protein content has been found to vary from 1·9% to 18% which has been attributed to the soil conditions, stage of maturity and characteristics of the species. With advancing maturity the amount of digestible protein and Starch Equivalent value decrease steadily, which fact is very significant from the practical feeding standpoint.

Hays

Maintenance and nitrogen balance experiments with typical hays have been carried out in several of the laboratories and a comparative study has been made of the digestibility of some of the fodders in the green state, as silage, and as hay. The work on the protein requirements for resting bullocks has shown that the minimum quantity of digestible protein required for the maintenance of a 1000 lb. bullock is about 100 grams per day and that when fed at this level the animal can be kept at nitrogen equilibrium.

Rice straw

In a study of the utilization by cattle of rice straw, which is the staple fodder in Bengal, Assam, Madras, some parts of the United Provinces, Bihar and Bombay, it has been observed that rice straw has a higher net energy value than that assigned to the American product. In the course of this work it has been found that excessive feeding with rice straw may produce persistent diuresis, due to the high potash content of the straw, and this may ultimately lead to a disturbance of the mineral metabolism of the animal.

Many experiments on the nutrition of growing animals have been carried out in different places. It has been found that most of the roughages by themselves do not form a maintenance or

productive ration and suitable supplements for meeting the protein or mineral deficiencies have been found to be necessary.

Pasture grasses

Pasture grasses have been the subject of several studies and interesting data with regard to their feeding values have been obtained. For example, it has been observed that the stage of maturity is an important factor in the nutritive value of these grasses, the pre-flowering stage and in-flower stage having the highest nutritive value which goes down rapidly with further maturity.

Physiological Problems

Experiments on the mineral assimilation from typical fodders have shown that the assimilation of lime is dependent to a considerable extent upon the phosphoric acid content. It has been found that some fodders are well provided with lime but its assimilation for a positive balance is entirely dependent upon a minimum quantity of phosphorus which must be present in the food. The results of certain experiments show that an animal of 750 lb. live weight on a maintenance ration requires a minimum of 10 grams phosphoric acid and 15 grams CaO per diem. Various other problems of a physiological nature have arisen in connection with different experimental works. For example, the acid-base balance of cattle urine has been studied with a view to determine the effect of ingestion of certain types of fodders on the excretion of acids in urine. Thus, the early cut fodders increase the volume of urine eliminated, which is attributable to a high amount of alkali in the food, but with advancing maturity the total fixed bases decrease and the *p*H of the urine tends to become lower. With certain fodders, such as hays, it is usual to find an increased production of hippuric acid, which appears to be the main form of detoxication of benzoic acid produced normally in the animal body on this type of diet. The question of sulphur metabolism in sheep with special reference to wool production has also been studied in several laboratories and sulphur and sulphate balance experiments have been carried out. No significant variation in the sulphur content of the wool or in its yield has been noticed as a result of inorganic sulphate feeding to sheep, although it has been observed that sulphate can be assimilated by the animal giving rise to an increased amount of organic sulphur which is usually excreted in the urine.

Fodder conservation

Considerable attention has been paid to the problem of the conservation of excess fodder either as hay or as silage. On the farms run by the Military Department, valuable work has been done on the cultivation and storage of fodder crops, but in villages much of the excess fodder, especially after the monsoon period, goes to waste because of faulty methods of preservation. In view of the limited fodder resources of this country, the question of the conservation of fodder is of the greatest importance. Work on silage making and losses on ensilage have been carried out in several

laboratories because silage is considered to be very useful as providing a form of succulent fodder during the dry months for milch animals and young stock. Experiments have shown that ensilage causes changes in the nitrogen content resulting in decreased protein value, but increases the availability of carbohydrates and the minerals. Attempts have also been made to ensile a mixture of green legume and dry wheat straw so as to produce a good quality silage, containing higher amounts of nitrogen, as also to increase the availability of carbohydrates from the straw diet.

A brief summary has been given above of the different studies which have been made during the last 15 years on the feeding of animals in health. In carrying out this work the problem of disease in relation to malnutrition did not receive much attention. A survey of the problem of malnutrition has, however, shown that due to deficient or faulty dieting large number of animals suffer from a state of chronic malnutrition which leads to loss of productive power, gives rise to various nutritional disorders and increases susceptibility to disease. For example, in many parts of the country, the milk yield of the cows is very low, sterility is common and mortality in calves is high. Various disorders such as bone diseases, reproductive troubles, blindness in calves, etc., are known to occur in many parts of the country as a result of malnutrition. In view of the close connection between nutrition and disease it is now considered necessary to study the subject of animal nutrition not only from the standpoint of the requirements of the healthy animal, but also from the standpoint of malnutrition in relation to susceptibility to disease, and although the problem is an all-India one, it has to be tackled regionally as well, as there may be considerable variations in the type of malnutrition observed in various parts of India.

With a view to study the more fundamental problems connected with nutrition in Indian animals it has recently been decided by the Government of India to establish a Central Animal Nutrition Institute at Izatnagar under the administrative control of the Director, Imperial Veterinary Research Institute. This, it is hoped, will give a considerable impetus to the study of this subject in this country and lead to a better understanding of the dietetic requirements for health, growth, productive capacity, and ability to resist disease of our animals.

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PROGRESS OF DAIRY HUSBANDRY IN INDIA DURING THE PAST TWENTY-FIVE YEARS.

By

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CONTENTS.

I. INTRODUCTION.

The development of the agricultural interests of India by the scientific departments of the Government dates back only to about 35 years. In the early days, the pioneering agricultural officers naturally devoted the major part of their energies to the improvement of the staple food crops of the people, and scientific development of the cattle-dairy industry did not receive much attention until within recent years. It was hardly realized that the money value of the animal husbandry products of India ran into crores of rupees every year and that out of this colossal amount, the value of milk and milk products alone amounted to over 350 crores annually. The most valuable pioneering work in developing the dairy industry in India has been done by the Military Dairy Farms Department of the Government of India. The medical authorities responsible for the health of the British troops stationed all over India became alive to the fact that the health of the soldier and his family

depended largely on a pure and safe supply of milk and milk products. To ensure this the military authorities established their own dairy farms at all the large cantonments in the country. This was the beginning of dairy farming on modern lines in India and the successful establishment of these huge concerns run on sound, scientific principles demonstrated to the country at large the possibilities of commercial dairying.

The Imperial Department of Agriculture in India, as apart from the Military Dairy Farms, first took up the question of the development of the dairy industry in 1906 when the then Director General of Agriculture in India founded the existing herd of pure Sahiwal dairy-cattle at Pusa. Within a short time of the commencement of the scientific and systematic improvement of the staple crops of the country, it was realized that if the success of the general improvement of agriculture was to be achieved and the fertility of the Indian soil maintained, cattle improvement must receive due consideration. The cow was required not only to provide motive power through its male progeny for the tillage of the soil and the haulage of crops in this country of small tenants, and for the provision of bulky manure for its hungry soils, but also for providing milk and its products for the physical welfare of its teeming vegetarian millions. The improvement of cattle in this country, therefore, became a question of improving the dairy husbandry and *vice versa*.

The development of this all important cattle-dairy industry of the country has been marked by definite stages in its progress. The first practical step seems to have been taken in 1916 when the Board of Agriculture in India gave a definite lead in this direction by making the recommendation that if the dairy industry of the country was to develop on proper lines it must receive expert guidance. This brought about the appointment of the Imperial Dairy Expert and the organization under him in 1920. This was very soon followed by the establishment of the Central Bureau of Animal Husbandry and Dairying, also a result of the efforts of the Board of Agriculture to help the industry. The Report of the Royal Commission on Agriculture (1926) indicated the lines on which the general uplift of the agricultural and cattle wealth of the country should be carried out and the means of achieving the same. One of the outcomes of the recommendations of the Royal Commission was the creation of the Imperial Council of Agricultural Research, which since its inception in 1930, has done its utmost in promoting the interests of animal husbandry and dairying. As the importance of the development of the dairy industry began to be realized, it was felt that apart from the organization required for the development of the general agriculture of the country, there should be a separate organization for promoting

the interests of animal husbandry. In accordance with this decision, institutions dealing with the subject of animal husbandry were separated from the Agricultural Institute of the Imperial Government in 1935.

As far as service to the dairy industry is concerned to-day, the only organization directly concerned with it is the one under the Imperial Dairy Expert comprising the Imperial Dairy Institute, Bangalore, and its affiliated stations. Soon after the creation of the Imperial Dairy Expert's post, it was realized that if the future dairy industry was to be built on sound lines, dairy education, the scientific investigation of the various problems connected with it and the necessary guidance to the men in the trade through advice, should form the three corner stones of the edifice. The efforts of this organization have, therefore, all along been directed in these channels. The Provincial organizations have supplemented these efforts towards the advancement of the industry mainly by the improvement of the cattle breeds indigenous to the various provinces.

Dairying does not merely imply the handling of milk and milk products, but the breeding, feeding and management of the dairy cow are equally important factors in the successful development of this important industry. In dealing with this subject, therefore, the writer has preferred the use of the words 'Dairy Husbandry' in place of 'Dairying' which is generally interpreted in rather a narrow sense.

II. Dairy Education.

Experience in the past indicates that whenever a dairy enterprise had proved unsuccessful, it was due more to its being put in charge of an untrained man than to any other cause. It was, therefore, realized that unless the trade was provided with the services of scientifically trained dairymen, capitalists would fight shy of investing their money in this industry. To deal with this situation the Government of India in 1923 established the Indian Dairy Diploma to be given to successful candidates after a two years' training at selected institutions. This training mainly aimed at turning out experienced dairy-farm managers who could organize dairy enterprises and run them successfully as commercial concerns. Hundreds of such trained men have now been made available to the dairy industry and have proved their worth. This training was further supplemented by a post-graduate course which aimed at preparing candidates for more advanced specialization in research work. At the same time the requirements of the ordinary man in the trade were not lost sight of as facilities

for the acquisition of practical knowledge of the latest methods of work were also made available. The effect of these facilities is apparent in the up-to-date town dairies and dairy farms which are springing up in increasing numbers all over the country.

III. Breeding and Milk Yield.

One of the first problems the enterprising dairymen had to face in starting dairies on commercial lines was to find a suitable dairy animal which would produce milk economically to make dairying a paying proposition. India has some excellent established breeds of cattle which have outstanding merits as compared to cattle of other parts of the world except in the matter of milk production. Indian cattle have wonderful stamina to stand the rigours of the tropics. Resistance to diseases is developed to a degree which can be claimed by no other bovine population of the world. But their performance at the pail is most disappointing. The attention of the early pioneers in dairying was, therefore, mainly directed towards such methods as could increase the milk of the Indian cow in the shortest possible time. They, therefore, resorted to crossing Indian breeds with some of the well-known Western dairy breeds of cattle.

The work done in this line for over 30 years, and mostly by the Military Farms Department, has yielded results of great interest although mostly negative in nature. The Shorthorn, the Jersey, the Guernsey, the Ayrshire and the Friesian were all tried out by turns with disappointing results as far as the creation of a new dairy breed was concerned. The method of introducing more European blood through the cross-bred progeny to Indian blood had each its own disadvantages. In the former case, although the cross-bred daughter gave more than 50 per cent higher yield than her Indian dam, the increase was not maintained in the subsequent generations. The progeny, as it advanced towards more European blood, lost the stamina, constitution and immunity possessed by its Indian dam, till in the end it degenerated into weed. In the other case, the introduction of more Indian blood in subsequent generations diminished the milk flow derived from Western blood with the loss of the special qualities of the Indian animal and the ultimate result was equally disappointing. This cross-breeding work brought out two outstanding facts that (1) although it yielded an immediate increase in milk, the increase continued for one or two generations only and it was possible under very limited conditions, and (2) cross breeding as a policy for the general improvement of the cattle wealth of the country was wholly unsuitable. About the same time, efforts were made

at acclimatizing European cattle to Indian conditions and breed them pure in the country. The results of these experiments have been none too encouraging although they are still being continued and are being watched with interest.

Experience has shown that the only sure way of improving the indigenous breeds for milk production was to breed them by pure line selection with the definite objective of developing a high milk-yielding strain. Where this system was adopted with the Sahiwal, Scindi, Hariana and Tharparkar herds established at different Government institutions, the results obtained have fully justified expectations. The comparative statement given below of the performance of various Indian herds shows that when systematically bred and reared, an Indian cow can increase its yield by 60 per cent within a span of only 11 years.

A herd each of the Hariana and Tharparkar cattle was started by the Imperial Dairy Expert at Karnal in 1923. The average yield per day over the two herds (cows in milk only) was 8·8 lb. in 1924. This rose to 13·2 lb. in the Tharparkar and 14·1 lb. in the Hariana in 1934. The following statistics based upon 568 lactations of the Tharparkar and 424 lactations of the Hariana show the improvement effected between 1923 to 1934-35 :—

	Tharparkar		Hariana.	
	Purchased.	Farm Bred.	Purchased.	Farm Bred.
Average milk yield in lbs.	2,294	3,791	2,379	3,634
Average days in milk	242	311	255	304
Average days dry	147	95	150	106
Average Overall in lbs.	5·6	9·1	5·6	8·8

Out of the 248 lactations completed by the herd which existed in 1932, 34 exceeded 5,000, 8 exceeded 6,000 and one exceeded 7,000 lbs. The highest yields reached are : Tharparkar 8,734 lbs. in 313 days and Hariana 7,412 lbs. in 344 days.

Details of progressive increase in milk yield shown by herds at Lyallpur, Karnal, Pusa and Ferozepore from the date of their establishment are given in the following table :—

	Average dairy yield in lb.				
	Lyallpur Agri. College Dairy	Karnal.	Pusa.	Ferozepore.	Overall.
First year ..	5·60	8·8	5·8	11·3	4·6
Second year ..	5·40	7·1	7·6	11·6	5·9
Third year ..	6·80	8·4	8·3	12·9	8·3
Fourth year ..	7·18	8·6	6·6	12·9	9·2
Fifth year ..	7·45	10·2	6·8	12·6	9·8
Sixth year ..	8·60	10·0	6·1	14·8	10·6
Seventh year ..	9·31	9·9	7·4	14·7	11·3
Eighth year ..	7·27	12·2	8·2	15·0	11·1
Ninth year ..	9·10	12·9	8·0	16·2	11·9
Tenth year ..	9·30	13·2	9·4	16·4	11·7
Eleventh year	9·03	13·2	10·8	17·4	12·5
Twelfth year ..	9·80	14·1	12·0	16·4	12·1

Within the comparatively short period of 20 years, one of the best known dairy herds of indigenous cattle has produced more than half a dozen cows yielding over 10,000 lbs. of milk in a lactation and more than a dozen gave over 9,000 lbs. of milk. Besides the Indian cow is a better butter producer than her Western sister or her cross-bred progeny. In this respect she has a strong rival in the other class of milch animal in India, viz., the buffalo. Systematic breeding of the buffalo has improved the fat content of its milk by over 50 per cent and in some cases the milk has been found to contain as much as 13 per cent fat, so that the buffalo could truly be called the cream or butter-producing machine of the country. As such, it plays an important rôle in the economics of the dairy industry in India. A systematic study of the performance of the two classes of animals has brought out the outstanding fact that under certain conditions unfavourable to the cow, e.g., where the fodder available is very coarse and the supply uncertain, the buffalo has proved to be a better dairy animal. The work done in the line of breeding of cattle has thus given a definite lead to the dairyman as to where he should look for the right type of milch animal and for what purpose. Another great step forward is the establishment of the pedigree 'Herd Books' for a few selected Indian milch breeds, so that at no distant date the dairy farmer will be in a position to obtain an animal with a known history instead of gambling with an unknown dairy cow purchased from the open market which he has at present to do.

IV. Feeding.

Next to obtaining a proper type of dairy animal, the problem that the dairyman in India was faced with was the maintenance

of the animal in an efficient condition of milking by proper feeding. The conditions peculiar to tropical countries of the world with regard to the obtaining of natural fodder for cattle are also to be found in this country. Most of the natural fodder grows only during the monsoon within a short space of about four months when the quantity obtained is more than what the cattle can consume. As a result more than half the quantity available is wasted either by the cattle trampling it down by being allowed to roam about unrestricted, or by the fodder turning rank and coarse and thus becoming useless for feeding. The cattle, therefore, as a rule have to maintain themselves on a starvation diet for the major part of the year. For a milch animal it is essential that it should be supplied with a regular and sufficient quantity of green or succulent fodder all throughout the year to maintain her milk flow. This gave rise to the search for the most profitable fodder crops available in the country. Experience has proved that crops like 'jowar', maize, berseem, etc., can not only be cultivated successfully as fodder crops, but in their food value they compare with the best fodder crops of the world. Where irrigation facilities were available, perennial grasses like lucerne, guinea, rhodes, napier and many others proved most successful for dairy farms. Some of these grasses gave record yields under favourable conditions, e.g., the yield of guinea and napier grasses have been recorded at 180,000 lbs. and 177,000 lbs. per acre in a year at the Imperial Dairy Institute, Bangalore. This means that an acre of such grasses would maintain about 20 cows in full milk throughout the year. After further experimentation it was found that such fodder crops when arranged in proper rotation not only supplied the requirements of a dairy herd throughout the year but they helped to maintain the fertility of the soil.

Where irrigation facilities, however, were not available, the question arose as to how to maintain the green fodder in a succulent form after harvesting. This resulted in the introduction of silage making in dairy husbandry. Different methods like tower, pit, trench and stack of making silage were experimented upon and it was found that pit silo gave the most satisfactory results being simple in design and cheap in construction. In this connection investigations were carried out to ascertain which crops were most suitable for ensilage and which was the best stage at which to harvest the crop for the purpose. Since its introduction, ensilage has become the sheet anchor of dairy farming.

At the same time work carried out on the natural grasses on the grazing areas indicated that most of them were lacking in mineral matter which was generally due to heavy rainfall and the general poverty of Indian soils. The deficiency of minerals in these grasses gave rise to certain deficiency diseases which greatly hampered the work of scientific cattle breeding. The investigations carried out indicated that addition

of minerals like ground limestone, iodine, bonemeal, etc., to the ordinary ration gave definite advantage in the growth of highly bred stock and the feeding of minerals in the necessary proportion has consequently become an adopted practice with most of the pedigree cattle farms in India. Amongst the many investigations carried out on feeding may be mentioned the study of starch equivalents for Indian foods, the determination of live weight of animals by measurements, the rôle of minerals in calf feeding, the digestibility of Indian coarse fodders, the digestive capacity of the Indian cattle, the carotene content of some of the important fodders and its assimilation by the Indian cow, the influence of progressive ripening of fodder on the mineral nutrition of cattle, etc. The methods of improving the feeding value of agricultural residues like paddy straw which is available in such large quantities also received attention. Experiments are being conducted on the utilization in the feeding of livestock on molasses, another important agricultural residue, to prevent its present enormous wastage.

Along with the roughage, the concentrates available in the country for the feeding of the dairy stock are being studied. The requirements of concentrates by dairy cows according to their milk yield were determined. This resulted in the fixing of feeding standards and their application to dairy cows in India. The economics of milk production in its relation to food was also ascertained. Investigation on the feeding of special oil-cakes like groundnut, cotton seed, etc., indicated that each one had a specific effect on the milk flow and the quality of the fat in the milk. For example, groundnut oil-cake tended to increase the milk flow, whereas cotton seed cake hardened the fat in milk which helped the dairyman to obtain butter of good ' standing up ' quality. The dairyman was thus able to know the best feeds for his stock and to compute rations so as to be able to get the most out of the money spent in feeding his stock.

V. Rearing and Management.

To stockmen all over the world it is known that systematic breeding and good feeding and management have an equal share in the improvement of cattle. In India, neglect in feeding and rearing more than breeding has brought about the present degenerated condition of the cattle. The rearing of a good cow starts from the fœtal stage, which means feeding the dairy cow when dry, a fact which was more or less unknown to the ordinary stockman, and, if known, was seldom acted upon. By experiments it has now been possible to lay down the kind and quality of food to be given to the dairy cow in the dry condition and while carrying. The systematic breeding of stock necessitated the recording of the exact performance of the cow. This led to the practice of weaning the calf at birth and pail-feeding and rearing it, which was considered

an impossibility with the Indian cow and the Indian *gowalas* at one time, but which has now become an established practice in all dairy institutions which are run on up-to-date lines. Pail-feeding brought in the question of determining the proper quantities of milk to be given to the calf in its early stages and the substitution of milk by other feeds like separated milk, gruel, grain meshes, etc., to economize milk for commercial purposes and at the same time to bring about full normal growth of the calf.

Systematic breeding also brought in its wake such important practices as recording the yield of the dairy cow morning and evening, maintaining her pedigree history sheet, recording any set-back due to diseases, etc., so that the whole economic life of the animal could be read at a glance.

Proper recording in its turn necessitated the numbering of animals for identification which in the case of the calf is done by tattooing the number on the ear by means of a specially devised machine. After maturity, however, there is difficulty in reading the number on the ear and the tattoo marks are, therefore, replaced by such identification marks as cutting notches in the ears, applying tin tacks in the ears and branding the number of a size large enough to be read from a distance. Experience of several years has indicated that for ordinary farm conditions branding numbers on the thigh was the most satisfactory method of identification. Experiments conducted on the comparative merits of branding numbers by hot iron and by a special chemical called 'branding ink' have proved that of the two the hot iron branding was more satisfactory as it was more humane, more lasting and did not damage the hide of the animal if carried out properly.

Another problem of economic importance which the dairyman was faced with was the late maturing and irregular breeding of the Indian dairy cow. Attention was, therefore, directed towards overcoming these difficulties in the development of the future dairy cow. Experiments were conducted in the force feeding of the animal in the calf stage and as a heifer and then subjecting her to special handling so that she would take the bull early. The animal was subjected to prenatling by being milked sometime before she actually calved, with a view to developing her bag to the utmost and improving its shape and thus encouraging increased milk flow as also avoiding udder trouble after calving.

Further important questions which received consideration were milking the dairy cow more than twice a day, the effect on the yield and quality of milk in relation to the time of milking and the intervals between milking, the percentage of fat as determined in the various portions of the milk during milking, the effect of incomplete milking on the quality of milk in subsequent milking and on the cow, the persistency in lactation, standardization of lactation period, the most effective period of a cow's life, quality and quantity of milk in relation to the advance in pregnancy, the effect of the season of calving on

subsequent lactations, etc. The study of the records of hundreds of animals helped to determine the rate of milk flow of the animal from calving onwards for a particular lactation so that the total yield for that lactation could be predicted fairly accurately by the use of a formula within a very short period of the calving of the animal. The study of correlation between body measurements and weight of cows and some points of body conformation helped in judging the animal as a dairy cow. In the case of irregular breeders, experiments proved that the injection of hormones helped to correct the defect. The work on the dipping and spraying of cattle conclusively proved that the highly bred dairy cow could be protected effectively against such common farm parasites as ticks, lice, mange, etc., and the health and efficiency of the animal could be ensured by this simple method which is within the reach of the ordinary stockman.

All this knowledge is of considerable practical importance to the dairyman and its study has tended to make the Indian cow a much better dairy animal than what she was. The results of the various investigations that have been conducted left no doubt in the minds of breeders that the Indian cow did respond to the treatment and management given to her in the same way as her sisters in other parts of the world, which have in consequence reached their present state of perfection.

VI. Production and Handling of Milk and Milk Products.

(a) *Milk.*

With the increased efficiency of the dairy cow, the disposal of the increased milk yield began to receive the attention of the dairyman. On account of the backward condition of dairying in this country and the uneconomic methods of milk production for supply to big cities, the problems facing dairymen were of two distinct types, urban and rural. The existing system of city milk supply in India is unknown in other parts of the world and if it at all existed, it was replaced by better methods years ago. One of the biggest problems facing large towns is the housing of milch cattle in the heart of the city. This, besides being quite uneconomical for milk production and being objectionable from the point of view of public health, began to deplete the cattle wealth of the country by the premature slaughter of prime animals taken to the city for milk production, as their maintenance became prohibitive during the dry period due to high rents and want of open areas in or about the cities. Conditions in the rural areas on the other hand were in such a primitive condition that milk could be sold as milk in good condition only within a very short radius of the place of production. The villager had no other alternative but to convert it into such handy products as *ghee* and *khova* which,

though in constant demand, hardly proved economical. Efforts were, therefore, directed in the early days to improve the quality of the milk itself so that it would be useful for the manufacture of more paying products and its keeping quality could be increased for being taken to distant markets. Educating the producer in the cleaner methods of milk production, though desirable, was slow. Methods had, therefore, to be thought out under which the milk could be accepted as it was offered by the producer and then processed in such a way as to render it safe and acceptable to the consumer. This resulted in the introduction of pasteurization in India about the year 1900. Pasteurization has been subjected to severe and varied tests, and it has proved to be an important factor in the economic advancement of the dairy industry. First the Flash method of pasteurization, which was in vogue at the time, was introduced. This was replaced by the Retarding or Holding method which in turn has given place to the Heat-exchanging method under partial vacuum. Refrigeration was a necessary adjunct to pasteurization, as the process was incomplete without chilling the milk at a fairly low temperature so as to retard the growth of bacteria in milk and keep it in good condition till it reached the consumer. This introduced for the first time in India the construction of cold stores and cold storage plants for commercial purposes as distinct from the manufacture of ice. The greatest handicap to the widespread adoption of pasteurization in the dairy industry in this country was the heavy capital cost of the plant. Experiments were, therefore, directed towards lessening the cost of the equipment by leaving out the chilling part of the process. The results were encouraging but the new process could be worked under certain conditions only. In order that the fullest benefits could be derived from processed milk, more up-to-date methods of bottling and distribution of milk were introduced.

Pasteurization

The introduction of more sanitary utensils such as the milking pail, milk cans, etc., and keeping them clean and sterile presented another problem. The one serious drawback to the utensils ordinarily used in the trade was their design which prevented satisfactory cleaning and sterilization. Hot water, live steam and different kinds of chemicals put on the market were all experimented upon by turns to find out the most efficient and economical method of sterilizing milk utensils and experience showed that for septic conditions, such as prevail in the tropics, there was nothing to equal steam.

Dairy utensils

The transportation of milk over long distances necessitated its homogenization. By forcing the milk through the homogenizer at a pressure of 3,000 to 5,000 lbs. per square inch, all the fat globules were broken up into minute particles which prevented their rising up to the surface and getting partially churned in transport.

Homogenization

Milking machine

Milking by machine was given several trials but proved to be unsuitable for Indian conditions. The first milking machine to be introduced in India was in 1915. Apart from the heavy initial expenditure, the milking machine gave satisfactory results only if the machine was maintained in clean and sterile condition which was very difficult on account of the unskilled nature of the labour in this country.

Quality tests

As the men in the trade became more enlightened, tests for determining the quality of milk, such as for fat, solids not fat, etc., began to be adopted and in the more advanced forms of dairying even determination of the cleanliness of milk through its bacterial contents by such methods as the Reductase test, plate counts, etc. was introduced.

In the production and handling of milk, some of the experiments of interest conducted were those relating to the most sanitary type of milking byres suitable for Indian conditions, the merits of pasteurizing and re-pasteurizing milk for increasing its keeping quality, shrinkage caused by pasteurization, economic study of bulk and retail delivery of milk and the study of the shape, size and number of fat globules in milk of various breeds with a view to ascertaining the most suitable one for butter and *ghee* production, market milk, cheese, etc. Though extremes still exist in this country in the methods of production and handling of milk, improved methods have now obtained a strong footing and some of the dairy institutions which have adopted the most up-to-date methods of production, handling and quality control of milk can rank with some of the best farm dairies in other parts of the world. Apart from milk itself, work done in connection with its products such as *ghee*, butter, casein, *khova*, cheese, sterilized milk and condensed milk and their relative importance is related below.

(*b*) *Ghee.*

Next to milk, *ghee* plays the most important part in the diet of the vegetarian population of the country. Nearly half the quantity of the milk produced in the country is converted into *ghee* and its money value is estimated to be over 80 crores of rupees annually. Yet it is still being manufactured in the most primitive fashion and is very difficult to obtain in a pure state to-day. The usual method of manufacture is to curdle milk by natural souring and then churn it by a very primitive device. The result is that there are various grades and qualities in the produce put on the market. *Ghee*-making is the least paying proposition for the dairyman. Its production is mostly in the hands of small cattle owners who have to resort to converting milk into *ghee*, only because on account of remoteness there is no other outlet for the milk. These conditions provide them with no incentive to introduce improved methods. Experiments have demonstrated that *ghee*

made from butter obtained by the Western method gives an increased yield of over 15 per cent besides being of superior quality to the *ghee* made by the 'deshi' method. The adoption of the better method, however, is difficult on account of the initial capital required for the equipment. Efforts are, therefore, being made to standardize an indigenous method which would be readily acceptable to the small producer and would produce as far as possible a product of uniform quality commanding a better price. Experiments are also being conducted to prepare *ghee* directly from cream so as to eliminate not only some of the appliances required but also time and labour. One of the great handicaps in the improvement of the *ghee* trade is the serious and unfair competition from *ghee* adulterated with such products as animal and vegetable fats. Science has not as yet perfected a simple test by which such adulterations can be easily detected. A study of the different standards adopted by the various municipalities for testing the quality of *ghee* indicate such great variations that they are hampering the *ghee* trade. Various investigations have been carried out on assaying growth-promoting factors to determine whether *ghee* could be substituted by any other animal or vegetable product, as pure *ghee* is so difficult to obtain. All of them have proved that pure *ghee* has no substitute for providing the animal fat required by the vast majority of the population in this country in their daily diet. Millions of tons of *ghee* are made to-day every year by nomadic cattle breeders who migrate from place to place with their stock. Due to the unhygienic methods employed, the *ghee* produced is of such a low quality that though it is pure it fetches a poor price. Experiments are, therefore, being carried out to refine this *ghee* by physical or chemical methods. The storage of *ghee* in good condition for long periods presented another problem. Much work has been done in studying the effects of heat, light and the kind of receptacle used on the keeping quality of *ghee*. The problem of the manufacture of *ghee* and its transport, storage and the detection of adulteration is so vast that all the scientific work done on it so far has merely touched the fringe.

(*c*) *Butter.*

Butter can be called a recent product of the dairy industry when compared to the other milk products indigenous to the country. Butter as butter was seldom used in this country till recent years, although it was manufactured for conversion into *ghee*. As manufactured by the Western method, its use increased with the European population in India and it is now spreading to Indians adopting Western standards of living. The money value of the annual turn-over of butter at the present day is estimated at Rs.60 lakhs. After the butter-manufacturing industry was established in this country, India was exporting large quantities of the

product to places like Burma, Ceylon, the Straits Settlement and as far as the borders of Russia, but this trade has now been more or less captured by other countries. The establishment of this industry introduced the mechanical separator for obtaining cream and the first separator to make its appearance in the country was in 1889. This forms one of the important landmarks in the progress of the Indian dairy industry. In fact its introduction marks a new phase in the dairy industry and that is of industrial dairying in the development of which lies the salvation of the industry. Soon after its introduction, the use of the separator began to spread to remote corners in rural areas where the milk was separated and the cream transported to large cities for conversion into butter. An improved outlet was provided for the milk produced in the country and an impetus was given to rural dairying. It was, however, soon realized that manufacturing butter on the spot and transporting it to the consuming centres was far better than transporting a bulky product like cream from the village to the city. As a result, separating stations were opened in the more important milk-producing areas and the cream obtained despatched to a centrally located creamery where it was converted into butter which was then packed and despatched to consuming areas. It was under such circumstances that the first creamery in India came to be erected in 1915 at Anand, the heart of the biggest milk-producing district in the country. The credit for pioneering work, even in this direction, also goes to the Military Dairy Farms Department. The Great War gave an impetus to the industrial system of dairying as the Anand Creamery produced on an average 130 tons of butter a month for the use of the troops in Mesopotamia. The example was copied by the enterprising dairy firm of Messrs. Polson & Co. of Bombay which established a creamery at Anand and designed and equipped it in a manner that makes it the biggest and most up-to-date creamery in the East and equal to some of the best creameries in the West. Both farm and creamery methods of manufacture of butter produced a crop of problems for the scientists. With the introduction of Western methods of butter manufacture, lactic culture starters for ripening cream came into use. Work was, therefore, carried out in isolating and fixing the aroma-producing lactic acid organism from 'dahi' to be used in cream ripening which would be most suitable for Indian conditions. Another problem that the butter manufacturer was faced with was the high acidity in cream obtained from out of the way places. Investigations were, therefore, carried out in the pasteurization and neutralization of cream to a standard quality product. Similarly, problems relating to the improvement of the flavour of butter, its salt and moisture contents, its packing, storage and transport, all received attention as they arose, till to-day it can

Separator

Creamery

Starter

Neutralization

be said that the method of manufacturing butter both on farm and creamery has been standardized to suit all climes and conditions, and it is now easy for the man in the trade to decide what to do.

(d) *Casein.*

The advent of the separator produced an additional by-product of milk, namely, separated milk whose disposal still remains a serious problem in areas where butter-making industry has established itself. Its use as a marketable product is at present very limited, due to the isolated position of the milk-producing areas. When separators were first introduced, it was a common sight to see this valuable by-product thrown away in open fields. In 1912 a German scientist had found a use for it in the manufacture of casein, but the whole process had remained a commercial secret till the outbreak of the War when the German was interned. The factory was then bought over by a private firm and the method of making casein was divulged. Casein, thereafter, became a cottage industry for the small stockman although it was made in a very crude form. The method consists of curdling the milk by some means and then sun-drying it after washing and pressing out the moisture. The casein thus obtained is of a poor quality and its demand for export trade is, therefore, limited. It is the one product of milk which, if manufactured up to the standards required by the foreign markets, has got a great future. Work is being carried out in improving its quality by trying methods of manufacturing it by mineral acids, lactic acid and rennet and on its washing and subsequent treatment.

(e) *Cheese.*

The annual import value of cheese amounts to Rs.7·6 lakhs. There are numbers of varieties of cheeses indigenous to the country but they belong to the soft cheese class and their method of manufacture is so crude that they cannot stand long transportation. Their importance and use is therefore limited to certain local areas. Another great handicap in the development of the cheese industry is the great prejudice to the use of 'rennet' in its manufacture by the vegetarian population. The use of cheese is, therefore, confined more or less to the non-vegetarian classes who have no religious objection to the use of animal rennet. The imported cheeses are mostly consumed by the European population and by big hotels. Attempts were made at manufacturing some of the

Hard cheese

foreign varieties of hard cheese in this country and they were fairly successful. The process of Cheddar cheese-making has now been standardized for the kind of milk obtainable, i.e., of the cow and buffalo, and to suit other

conditions prevailing in this country. Similarly, the process of manufacturing some of the indigenous soft cheese varieties have been standardized after considerable scientific investigation. Of late, attention has been paid to finding a suitable substitute for the animal rennet and using vegetable rennet so that the use of cheese in the daily diet may become more widespread, thus producing additional outlet for milk.

Soft cheese

(*f*) *Sterilized Milk.*

Though there are no exact figures available of the quantity of sterilized milk consumed in this country, there is a fairly well-established demand for it, more especially from boats touching Indian ports and for infant-feeding. Certain conditions peculiar to India offer great possibilities for developing this branch of the dairy industry. For example, there are tracts of India where large herds of cattle are maintained mainly for the production of improved type of animals. The production and handling of milk in their case is of secondary importance, as the remoteness of the places present serious difficulties in the disposal of such milk. Milk is therefore more or less wasted in such areas. If, therefore, sterilization of milk is introduced in such tracts, it would not only make cattle-breeding more remunerative, but with the possibilities of keeping sterilized milk indefinitely and transporting it over long distances it can be made available in areas where there is a great paucity of milk. That trade in sterilized milk can be established in this country was proved by a long series of experiments conducted for over a period of four years in the sterilization of milk in bulk and in bottles by Mentor's process. As in all scientific investigations, difficulties were at first experienced in keeping the bacterial growth of the milk under control in bulk sterilization, but they were soon overcome and the method proved a success.

(*g*) *Condensed Milk and Milk Powder.*

According to Customs figures, India to-day imports milk products from foreign countries in the form of condensed milk and milk powder and its other preparations to the tune of 0·7 crore of rupees annually. This indicates the immense possibilities which lie in the manufacture of these products in this country and of thus providing a better outlet for the raw material which at present is stagnating in most of the rural areas. Preliminary experiments were carried out in the manufacture of condensed milk with a view to the better utilization of the village-produced milk and they yielded encouraging results. Samples of condensed milk, both whole and separated and sweetened and unsweetened, were successfully manufactured and the results are now required to be tried out on a commercial scale. No systematic investigation work has, how-

ever, been carried out on the manufacture of powdered milk, though it is one of the products which has great possibilities for internal as well as external trade.

(*h*) *Khova or Mava.*

This is one of India's indigenous products which has an annual turn-over of Rs.10 crores per annum. It represents milk in a partially desiccated form and is mainly used in the manufacture of confectionery. Like *ghee*, it is a poor paying proposition for the dairyman, but he is compelled to manufacture it because in the first place he has an assured market for the product and secondly, because he cannot find any better outlet for his milk.

VII. Matters of General Interest.

While progress on the scientific side of dairying was satisfactorily achieved, there was little hope of making any headway against such difficulties as unfair competition from adulterated products, the grip of the money-lender over the producers, etc. in this country of small holdings unless the producers were properly organized. Co-operation was considered to be the only feasible method of bringing about the salvation of the small producers. Early efforts were, therefore, directed towards organizing the dairy-cattle industry on a co-operative basis. This method was found to be pre-eminently suitable for the supply of milk to cities from rural areas and an example of this is provided by the Co-operative Milk Union of Calcutta.

This involved the adoption of the creamery system of dairying in rural areas, the need for which in the future advancement of this important industry cannot be over-emphasized. Denmark provides a living example of what can be achieved through co-operation as applied to the dairy industry in a country of small holdings and where the industry is organized on creamery basis. India in one respect is more suitable for the development of village dairy creameries than most of the countries which have adopted this system because of the fact that cattle are kept in the villages and are thus grouped together in centres close to where the creamery would be situated. These might take the form of creameries for butter manufacture and pasteurizing and chilling milk for despatch to the cities, milk condensories, casein works, dried milk and *ghee*-making centres. The establishment of such creameries not only provides a better outlet for milk from rural areas, but the development of the village dairy means more employment to the farmer and his family in the rearing, feeding and milking of his cattle. The breeding of an improved type of cattle would be taken up seriously as a business proposition only if the produce of the cow, viz., milk, can find a proper outlet and can fetch a good

price for the owner. Unless, therefore, the creamery or industrial system is introduced in rural dairying and the flow of milk diverted to urban areas from its existing uneconomical channels, the urban population will continue to get an unhygienic, impure and costly supply of milk and the wanton destruction of the cream of the cattle wealth of the country will continue. The Gujerat district of the Bombay Presidency, where the butter industry has established itself, provides an illuminating example of how prosperity for the countryside follows in the wake of the industrial or creamery system of dairying.

The above chronological statement of events would be incomplete without a reference being made to the valuable work carried out by the recently started marketing surveys (since 1935). As a measure preceding actual development work, preliminary surveys, in respect of agricultural commodities, such as wheat, rice, oilseeds, fruits, milk, *ghee,* hides and skins and eggs are already undertaken. The Agricultural Produce (Grading and Marking) Act, 1937, is the outcome of the activities of this department and this will enable approved traders to grade and mark argicultural and animal produce according to the standards laid down by the Act. A *ghee* conference was recently held at Simla where the *ghee* merchants agreed to grade and mark *ghee* according to the above Act. Thus a start has already been made in the proper grading and marking of dairy produce so as to provide an incentive to the producers and traders to deal in improved quality products.

To recapitulate, the progress of the dairy industry of the country depends upon an improved type of milch animal. Improvement of the milch animal can only be achieved if a better outlet can be found for the increased quantity of milk from the improved cow. This in turn means helping the trade with men trained in the technique of dairying and assisting it to solve its many problems through scientific investigations. Co-operative organizations will be necessary to free the small holder from the clutches of the money-lender and to bring within his reach the many advantages which can otherwise be obtained only by large investments. The industrial system of dairying will have to be established in rural areas to ensure for the producer a constant demand for his produce and an organized market which allows him a reasonable price for his commodity. Lastly, legislative control is necessary to protect the producer of genuine and wholesome products against unfair competition. Then and then alone can progress be achieved in the improvement of the cattle wealth of the country and milk and milk products of assured quality brought within the reach of the poor classes, thus catering for the prosperity and welfare of the nation.

Dairy husbandry, as understood in the foremost dairy countries of the world, is still in its infancy in this country, but there has

been some progress since its birth even against odds. With the general awakening which has come all over the country and the lead given in the right direction by His Excellency the Viceroy, the future is pregnant with great possibilities. It is to be hoped that before long India will be able to range herself with the foremost dairy countries of the world.

‘THE PROGRESS OF ARCHÆOLOGY IN INDIA DURING THE PAST TWENTY-FIVE YEARS.’ [1]

By

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Contents.

I. Introduction.

Before considering the progress of Archæology in India during the past twenty-five years, it would be worth while recording the state of archæological studies at the beginning of this period. Indian archæology has just completed a century of its existence, commencing from the time when James Prinsep deciphered the ancient Brāhmī script of India and laid the foundations of an exact knowledge of India's past, based on an understanding of contemporary records. Systematic archæology, however, can be said to have had its birth after the country had settled down subsequent to the turmoil of the Mutiny of 1857 and with the institution of an Archæological Department of India under the direction of General Sir Alexander Cunningham in 1862. During the first twenty years, General Cunningham and his Assistants carried out an exhaustive survey of the monuments and antiquities of Northern India and work was started simultaneously on similar lines in the Bombay and Madras Presidencies. After a short-lived experiment in 1885 of a Director General charged with the duties of conservation as well as research, archæology fell under the shadow of retrenchment in 1889, when except for an Epigraphist in Madras, a Surveyor in Bombay and another in the United Provinces, India was practically bereft of any archæological officers. It was left to the determined energy and love of antiquity of Lord Curzon to organize a proper

[1] I must here record my appreciation of the valuable help I received from Mr. G. Yazdani, Dr. M. H. Krishna, Mr. M. B. Garde, K. B. Sana Ullah, Rai Bahadur Prayag Dayal, Dr. Chakravarti, Mr. Krishnamacharlu, Mr. T. N. Ramachandran, and Mr. N. G. Majumdar in the preparation of this chapter.

Archæological Survey for the whole of India, and place it on a sound administrative and financial footing. The appointment of Sir John Marshall (then Mr. Marshall) to the post of Director General of Archæology in 1902 heralded a new era of archæological activity in India.

During the first ten years, Sir John Marshall's task consisted of organizing, developing and perfecting the machinery of the Archæological Survey in this country in every direction. Thus the loose-knit Circles of India were welded together by the presence at the centre of a single head whose existence ensured a uniform and liberal policy in matters of research and the preservation of monuments, as also in the encouragement of epigraphical studies and the establishment and development of museums. The inauguration of systematic excavation in India and the introduction of scientific methods as evolved in Greece, Italy and other Western countries, stand to the credit of Sir John Marshall. Owing to the fact that the previous work of the Survey under General Cunningham was concentrated more or less on the problems of the ancient geography of India, with particular reference to the Buddhist sites visited by the Chinese pilgrims, it was at first thought advisable by the newly constituted Survey to re-examine these sites and control the results obtained by an earlier generation of investigators. Thus excavation work was done at Rajgir, Sahet-Mahet, Kasia, Sarnath, Mirpur Khas, Peshawar and other places in North India, before it was decided to commence operations in a more extensive and entirely unexplored field, viz., that of laying bare the stratified remains of ancient cities and bringing to light material illustrative of the life lived in these cities centuries ago. The only city sites excavated before 1912 were those of Bhita near Allahabad where Sir John Marshall discovered well preserved remains of houses, shops and streets, dating as far back as the Mauryan epoch, and of Basarh, the ancient Vaiśālī in the Muzaffarpur District of Bihar, where Drs. Bloch and Spooner unearthed a surprising number of inscribed terra-cotta seals and other antiquities from pits dug at intervals. These discoveries were the first fruits of a policy of breaking new ground, and the rich harvest, which has been eventually gathered during the last twenty-five years, is due to the steady and unceasing efforts continued by the Survey under the direction of Sir John Marshall.

In spite of over three quarters of a century's effort in the field of Indian antiquities, the starting point of Indian archæology in 1912 remained unchanged and the birth of Buddha remained a landmark beyond which Indian investigators never hoped to penetrate. In the first half of the period under review this state of stalemate still continued, but the new light on the most ancient civilization of India, which was thrown by the discoveries at Mohenjodaro and Harappa in 1924, quickly transformed the conception of Indian archæology, and the age of Indian antiquities,

instead of being reckoned in centuries before the Christian era, was at one stroke carried back several millennia before the birth of Christ and centuries before Abraham lived. The period from 1925 to 1931 (when the advent of a cycle of world depression arrested all further progress), can be described as a boom period, such as it had never been the good fortune of Indian archæology to witness. The momentum gathered by Indian archæology during these years of activity and the status which India had obtained in the international world of antiquity are reflected in the keen interest taken in problems concerning India's past both in this country and abroad. It is hoped that the financial difficulties, which caused an abrupt cessation of activities at a time when archæological studies had entered a most interesting phase, have been successfully tided over and a smooth and regular course of development is in store for the future.

II. Excavations.

Taxila

To resume the chronicle of archæological activities from 1912, it may be stated that in this year were commenced the epoch-making excavations at Taxila which almost continuously engaged the attention of Sir John Marshall until his departure from India in 1934 and which still form his chief preoccupation in his retirement. Here is a city on the great highway connecting the North Indian plains with the highlands of Central Asia and Iran, which formed, as it were, the crucible in which the cultures of the indigenous races were blended with those of the invading races, Greek and Persian, Scythian and Parthian, and which finds prominent mention in the accounts of Greek historians and in early Indian literature as a wealthy city as well as a seat of learning. The high expectations raised by the investigations at such a site have been amply fulfilled by Sir John Marshall's work continued for over two decades. The operations at Taxila have covered about a dozen different sites within an area of some 25 square miles, embracing three separate cities and more than half a dozen Buddhist establishments of considerable magnitude. The earliest of the cities is the pre-Greek city at the Bhir mound site which has yielded, among other early antiquities and objects d'art, important hoards of punch-marked coins which have added so considerably to our knowledge of the earliest currency of India. The most intensive work has been done at the site of Sirkap, which was the second city of Taxila, founded by the Indo-Greek kings and apparently evacuated in the second half of the 1st century A.D. The lay out of the town with the regular arrangements of streets, lanes and houses has been carefully uncovered, stratum by stratum, and thousands of coins, gold and silver jewellery, bronze statuettes and stucco figures, domestic utensils and other objects which were discovered have now been preserved

in the beautiful Museum erected near the site. The third and latest city site named Sirsukh which pertains to Kushān times has so far been examined only partially.

Among the Buddhist sites, the one nearest the city and the most prominent and extensive is the Chir Tope, or Dharmarājikā Stūpa, a gigantic establishment with a lofty central Stūpa (said to have been founded by the great Aśoka), surrounded by scores of smaller votive Stūpas, chapels, and extensive monasteries. The hills in the vicinity of the city of Taxila provided beautiful retreats for Buddhist monks, and the remarkable finds at the hilly suburbs of Jaulian, Mohra Moradu and Kalawan provide ample testimony to the way in which the pious citizens loved to endow their religious establishments.

Pāṭaliputra

The other city site of Pāṭaliputra, the capital of the Empire of the Mauryas, which Dr. Spooner commenced to excavate in the same year (1912), unfortunately offers a far less favourable field to the systematic excavator. Here, the accumulation of some 20 or more feet of alluvial silt deposited by the waters of the Ganges and its tributaries makes it well nigh impossible to recover the regular plans of the houses or the lay out of the streets. Dr. Spooner's work brought to light traces of the palace of the Mauryas, with its roof supported on a hundred stone columns, which, it was pointed out, was based on the prototype of the throne-room of the Achaemenian Emperors at Persepolis. The more elaborate conclusions regarding the influence of Iran on the early history of India, which Dr. Spooner based on his finds, were much criticized at the time, but a substratum of truth regarding Iranian influence has found a universal acceptance. Excavations were carried out at Bulandibagh for a number of years, in course of which a number of wooden structures—part of the famous palisade of the city—and a remarkable caché of terra-cotta figurines was discovered. Recently quite a wealth of material of Mauryan age of artistic and technical importance including magnificent examples of the lapidary's art has been brought to light from the lower levels by sewage operations carried out in the city of Patna, which it would have been almost impossible to obtain by regular excavations.

Sāñchī and Besnagar

In 1913-14 Sir John Marshall commenced his exploration at the site of Sāñchī where he laid bare the entire complex of Stūpas, monasteries and temples on the upper plateau. The way in which these noble monuments of Buddhism—the best preserved structural relics of this faith in the country of its birth—have been conserved reflects great credit on the Bhopal Government. Within a short distance from Sāñchī is Besnagar, comprising the ruins of the ancient Vidiśā, where work was commenced in the same year by Dr. D. R. Bhandarkar and was financed by the Gwalior State. Here were discovered the remains of an ancient temple of Vāsudeva,

which is among the oldest of shrines dedicated to the Vaishnavite deities.

Works during the War and Post-War period

During the next few years (1914–1922) the Great War and the post-war conditions proved a great handicap to the progress of research in the archæological as in other scientific fields. The only excavations which were conducted throughout this period were those at Taxila, where Sir John Marshall continued to bring to light fresh groups of Buddhist Stūpas and monasteries and extended his researches to the lower strata of the successive cities. The site at Sarnath came in for some fresh excavation in 1914-15 at the hands of Mr. H. Hargreaves, who brought to light some important dated sculptures of the Gupta period and a number of unique heads and other antiquities of the Mauryan period.

Nālandā, Mirpur Khas, Sarnath, Taxila, etc.

In 1916-17 the Royal Asiatic Society's grant enabled Dr. Spooner to commence work at Nālandā, which has continued unabated for two decades, the bulk of the work being accomplished by Mr. J. A. Page. The complex of Stūpas, temples and monasteries brought to light at Nālandā afford a unique insight into the development of Buddhism in Eastern India during the later centuries of its existence, and the wealth of epigraphical and artistic material recovered from this seat of learning is indeed remarkable. In the same year Professor Bhandarkar carried out excavations at the site of Mirpur Khas in Sind where six years previously a Stūpa had been opened up by Mr. Cousens. Professor Bhandarkar's discovery consisted of a court of votive Stūpas and remains of monasteries dateable to the 6th century A.D. In 1917-18 the late Dr. Tessitori, a young Italian scholar carried out some interesting explorations in the Bikaner State, bringing to light some interesting terra-cotta and ancient burial mounds, which unfortunately have not since received the attention of explorers. In 1918-19 some work was done at Sarnath, but archæological activities were mostly at a standstill. Some more interesting discoveries from Taxila including Mauryan and pre-Mauryan antiquities from the earliest city at the Bhir mound site and the exploration of a small mound at Shalihundam in the Ganjam District by Mr. A. H. Longhurst are the only mentionable works.

Archæology after Reforms of 1919

In the next year (1919-20) there was also some more work at Taxila and Nālandā, but the inauguration of the Reforms of 1919 opened a new chapter in the constitution of the Department. Archæology, which was hitherto receiving divided attention from the Provincial and Central Governments, became the sole charge of the Central Government from 1921. The Epigraphical Department was entirely reorganized, a new Circle was started for Bengal and Assam, and the Archæological Section of the Indian Museum, Calcutta, was entrusted to a whole-time Superintendent. From

the year 1921-22 the Archæological Department began to issue its Reports in a consolidated form instead of each Circle issuing a separate publication. During this year work was confined to Jamalgarhi in the Frontier Province, where some annexes of the Buddhist monasteries were brought to light, and to Sarnath, where some further work was done.

Discovery of Mohenjodaro

The most epoch-making finds, which changed the course of archæology thereafter, were made in 1922-23 when Mr. R. D. Banerji excavating the ruins of a Buddhist Stūpa at Mohenjodaro in Sind came upon certain seals with pictographic characters, which were till then known only from the site of Harappa in the Punjab. The full significance of the discovery was, however, not apparent till the summer of 1924 when Rai Bahadur Daya Ram Sahni's finds from Harappa and Mr. Banerji's Mohenjodaro antiquities were compared by Sir John Marshall, who perceiving the importance of Mr. Banerji's discovery, immediately brought the existence of this ancient prehistoric civilization to the notice of Western scholars. As Sumerian scholars were the first to point out the striking affinities between the antiquities and particularly the scripts found from the Indian sites with those from Southern Mesopotamia, the newly discovered civilization was at first called Indo-Sumerian. Later, as it was found to be prevalent throughout the Indus Valley, which appeared to be its main, though not the exclusive habitat, it was re-named as the Indus Valley civilization.

Increased grant for excavations; further work at Indus Valley sites

From the year 1924-25 onwards the Government of India liberally financed the schemes of exploration and research in the various parts of India, thanks to the great stimulus afforded by the discoveries in Sind and the Punjab. In place of some Rs.20,000 to Rs.30,000 usually allotted for the purpose of exploration for about twenty years, a sum of about Rs.50,000 was sanctioned during the year 1924-25, which was increased to Rs.1 lakh from the year 1925-26 and Rs.2½ lakhs in 1926-27 and subsequent years. In 1924-25 it was left to the writer to take charge of the work at Mohenjodaro after the importance of this site had been recognized for the first time. On the extensive site, which covers about a square mile of rolling mounds, a number of trenches were dug to expose the nature of the structures hidden. The results obtained were sufficient to demonstrate the existence of a widespread city and the character of its antiquities, of which over 7,000 were registered during the season. Similar operations continued at Harappa by Rai Bahadur Daya Ram Sahni further increased our knowledge about the site at Harappa. During the next year almost the whole resources of the Department were concentrated at Mohenjodaro under the personal direction of Sir John Marshall, and several mounds were simultaneously

explored. After 1927 work in this field was entrusted entirely to Dr. E. J. H. Mackay, a scholar who had experience of excavations in Egypt, Palestine and Mesopotamia, the last work with which he was associated being the great city of Kish. The results of activities at Mohenjodaro during the period up to 1927-28 have been published in three large volumes by Sir John Marshall, while the subsequent work at the site under Dr. E. J. H. Mackay is the subject of a large monograph from the pen of the excavator. It is difficult to summarize the extensive researches carried on at Mohenjodaro during a decade. It may be sufficient to note that in the name Mohenjodaro is epitomized the entire progress of Indian Archæology during the last decade and half.

Mohenjodaro and Harappa

Briefly, the ruins at Mohenjodaro are those of an extensive and well-planned city that flourished some time between 3100 and 2700 B.C. and was deserted in the middle of the third millenium B.C. It was never again occupied except that a lofty mound representing perhaps its principal religious establishment was rehabilitated for a few centuries after Christ, and crowned with a Buddhist Stūpa surrounded by monastic cells. The excavations have revealed a city in better preservation than any other ruins of a later period found in India, and the civilization unearthed betokens civic life in advance of the contemporary cities of Sumer and Egypt. The stage of culture can broadly be expressed as chalcolithic, although the use of stone implements was confined to certain forms like scrapers, while the only metals included were gold, silver, copper and bronzes (except iron). One of the most fascinating problems connected with the people is the pictographic script employed in their personal stamp seals and other inscribed objects, which has yet baffled the ingenuity of scholars. Some of the buildings such as the Great Bath at Mohenjodaro and the Great Granary at Harappa are unique, and show the advances made in architecture. The civilization seems to have been developed by a race of practical people with commercial instincts, although a great advance in agriculture must have preceded the establishment of these cities. The evacuation of the city is held to have been hastened by recurring inundations of the Indus, but invasions of other tribes may also have been an important factor. The date of the civilization is fixed by the occurrence of definite products of this culture in certain dateable strata in Sumerian sites. It has, however, not yet been possible to trace the further stage or development of the culture and the gap of about 2,000 years between its disappearance and the advent of the Buddhist age has not yet been successfully bridged.

Further work at Harappa

The work at Harappa was continued from the year 1926-27 onwards by Pandit M. S. Vats at the point where it was left by Rai Bahadur Sahni. The results of his researches are comprised in a

Monograph of considerable size, which is shortly expected to be sent to the press. Among the most important finds at Harappa may be mentioned the remains of an ancient burial ground in two strata, which has added considerably to our knowledge of this ancient culture.

Explorations in Baluchistan

In 1925-26 Mr. Hargreaves explored several sites in Baluchistan including a very interesting site named Nal, where from an ancient cemetery he found polychrome pottery of an entirely different type which throws important sidelight on the civilization of the Indus Valley. The work in Baluchistan was further continued by Sir Aurel Stein in the years 1927-28 and 1928-29, and a large number of sites including some with marked affinity to the Indus Valley sites were discovered. The work of this veteran and indefatigable scholar, who is still exploring in Southern Iran, has brought to light more material in this tract, so as to complete the chain of ancient culture from India to Sumer and makes it possible to frame a reasonable groundwork of the ancient history or prehistory of Western Asia.

Prehistoric Survey of Sind, etc.

The extension of the Indus Valley civilization was followed in other directions by different investigators. Antiquities almost exactly comparable to the types found at Mohenjodaro and Harappa have been discovered by Mr. Vats at Rangpur in the Limbdi State of Kathiawar and at Kotla Nihang in the Ambala District of the Punjab. Within the boundaries of Sind itself the work of Mr. N. G. Majumdar has brought to light over 20 chalcolithic sites, mostly on the right bank of the Indus and in particular in the hilly regions between the Indus and the Khirthar range. Prominent among these sites are Amri (which yielded a new pale-ware culture below the black on red pottery of the Mohenjodaro epoch), Lohumjodaro, (with a later phase of the Indus culture), Manchhar lake sites (where a lake-dwelling section of the Indus culture was found), Ali Murad (an extensive settlement near the Khirthar hills), Damb Buthi (where a prehistoric burial site was found), Pandi Wahi and Chauro Landi (whence came a fine polychrome pottery) and Kohtras-buthi (where a fortified hill settlement of prehistoric times was located).

Chanhudaro

The only important site on the left bank of the Indus discovered by Mr. N. G. Majumdar is Chanhudaro in Nawabshah District, which has since been the scene of activities of the first Expedition from abroad, working with a license under the provisions of the newly amended Ancient Monuments Preservation Act. This was the Expedition organized by the American School of Indic and Iranian Research and the Boston Museum, and directed in the field by Dr. Mackay. The first season's work in 1935-36 was highly interesting and fruitful, several important results from the stratigraphical point having

been achieved and interesting finds having been made. This work has not unfortunately been resumed.

Scope of future research

Very recently a number of sites in the Central Punjab have been reported and with more extended investigation in Rajputana and the upper Gangetic valley it is hoped that the influence of the Indus civilization will be found to have extended over a much wider area than was at one time supposed. The greatest hopes of the future are centred in the Gangetic valley, where hundreds of unexplored sites are still awaiting examination, which must hold the secret of the course of India's civilization during the period intervening between the prehistoric and the historic periods, still separated by an unbridged gulf of some 2,000 years. Unfortunately the preoccupations in Sind and Punjab prevented any attention being devoted to the almost virgin field awaiting the explorer in the heart of Hindustan, but it is expected to commence work here at an early date.

Bengal

The increased amount available for field research in the latter half of the third decade made it possible to extend the scope of excavation to the Province of Bengal which had almost been untouched. The most prominent site in Bengal is that at Paharpur, where work was begun as early as 1923 but was regularly taken in hand for excavation from 1925-26. The discoveries at this place consist of a gigantic monastic establishment of the Pāla period surrounding a towering four-storeyed temple, the walls of which were embellished by stone reliefs and terra-cottas throwing new light on the early history of art in Bengal. The work was continued almost wholly by the writer up to the year 1933-34, in which year a later temple complex with a number of important minor objects was brought to light. Work in Bengal was also extended to an important city site, viz., Mahasthan, the ancient capital of North Bengal, during the season of 1928-29, when important results were achieved. Recently an outlying mound in the suburb of the city has been excavated and found to contain a large temple supported on a number of walls with a curious honey-combed appearance. Work on a small scale has also been done at the sites of Baigram in Dinajpur District, Mahanad in Hoogly District and Rangamati in Murshidabad District, but owing to the humidity and subsoil water in Bengal it seems very unlikely that any excavation can successfully be extended to the remains of a date earlier than the Christian era. The earliest site in Bengal brought to light only a few months ago is a late neolithic site near Durgapur in Burdwan District, which is being examined during the present season.

Bihar

In Bihar, besides the great work at Nālandā and Pāṭaliputra referred to above, the sites of Lauriya Nandangarh in the District of Champaran and Rajgir in Patna District have been recently taken in hand. At the

former site, besides a number of Stūpas of early type, a gigantic monument with several angular projections has been unearthed by Mr. N. G. Majumdar. At the latter site Mr. G. C. Chandra has brought to light the remains of an early centre of the Nāgas—a cult of obscure origin but widely prevalent to this day.

Madras Presidency

Except for excavation on a small scale the Madras Presidency has never had any large scale work done at any of the sites with which it is teeming. The find of skulls and other objects in a prehistoric cemetery at Adichanallur gives a glimpse of the possibilities of the sites in the extreme south of the peninsula, but unfortunately this work has not yet been organized. The only systematic excavation on a large scale done during this quarter of a century was during the years 1926 to 1930 by Mr. A. H. Longhurst at Nagarjunikonda in the Guntur District in the valley of the Krishna and consisted of the excavation of a number of monuments including Stūpas, chaityas, monasteries, etc. The inscriptions and bas-reliefs discovered here constitute a remarkable series and form extraordinarily rich material for the cultural history of the lower Krishna valley in the early centuries of the Christian era.

III. Museums.

Central Asian Antiquities Museum

The remarkable development of Indian archæology during this period has been responsible for the growth of Museums devoted to archæology. Of the ten museums for which the Archæological Department is responsible, six have been constituted during the last decade. The most important of these is the Museum at New Delhi, which houses the antiquities recovered by Sir Aurel Stein in his successive Central Asian explorations, of which the last and most fruitful was accomplished during the years 1913 to 1916. The ancient relics discovered in the sand buried and desiccated regions of Chinese Turkistan belong to a civilization in which Chinese, Tibetan and other elements are apparent, but Indian inspiration is paramount. The remarkable fresco paintings, hundreds of beautiful silk paintings, most of which were obtained from the Cave of Thousand Buddhas, the wonderful textile fabrics and a variety of documents, furniture and household stores, brought back by Sir Aurel Stein constitute a unique treasure for which the Government of India provided a special building in the planning of the new capital. The construction of a Museum worthy of the capital of the Indian Empire is now under contemplation and it is hoped that before long this will be an accomplished fact. The collections in the Museum have been recently augmented by the finds from Baluchistan and Sind.

Taxila and other Museums at excavation sites

Another excellent addition to the Museums of India is the Taxila Museum, which was established in 1928, and both as regards its planning, equipment and collections it stands among the best institutions of its kind in this country. The progress of the excavations at Mohenjodaro, Harappa and Nālandā necessitated the arrangement for housing on the site the antiquities discovered from year to year. A Museum of the open court type is being constructed at Nagarjunikonda in Guntur District to house the large number of sculptures discovered at this site. Recently the scope of the collections in the local Museums has been more clearly defined, and the duplicate antiquities available have been distributed to other museums so as to facilitate a wider study of the antiquities.

Indian Museum, Archæological Section

The most important collection in the charge of the Department is the Archæological Section of the Indian Museum, Calcutta, which has shown remarkable development during the last 25 years. In spite of the fact that no additional galleries have been constructed, the existing space has been fully utilized in the systematic re-arrangement of the collection which illustrates almost every class of antiquity found in every part of India. Among the new acquisitions during this period may be mentioned the representative collections from Mohenjodaro, Nālandā, Taxila, Sarnath and other sites excavated by the Department, a fine collection of gems from General Pearse's collection, besides several sculptures from Central India, Bengal and Orissa.

Museum movement

A word must here be said about the growth of the provincial Museums, some of which, notably those at Bombay and Patna, have been established and developed entirely within this period. Other Museums that have shown considerable activity are those at Madras, Lahore and Muttra. The whole subject of Museum activity and Museum development has recently gathered great momentum as a result of the publication of a report by Messrs. Markham and Hargreaves, who recently surveyed the Museums of India on behalf of the Museums Association of Great Britain. Much progress is expected during the coming years, particularly if the Museum Conference again becomes a regular feature and the authorities responsible for the administration of Museums in India support the movement more liberally than before.

IV. Conservation.

Preservation of Monuments—a Central charge

One of the most important activities of the Archæological Department and in fact one which accounts for the bulk of the expenditure is that of preservation of ancient monuments. Twenty-five years ago conservation of monuments was a

provincial charge, the Government of India only giving specific grants-in-aid when some work beyond the capacity of provincial budgets was undertaken. Since the Reforms of 1919 the preservation of monuments all over India became a central charge and thus the important work of preservation for posterity of the relics of the past was subjected to a unified and central control, and the element of uncertainty of funds available for this national work was removed. So far as the work of preservation is concerned India may be said to be much ahead of West Asiatic countries, where little systematic effort is made, apart from measures carried out by private parties or by expeditions in respect of the monuments or sites in which they are interested. Considering that the forces of nature such as rain, earthquake, storms and heat play great havoc in monsoon lands like India, and the great pressure of population on the land tends to remove vestiges of older settlements by irrigation and by removal of stones, bricks and earth for building and agricultural purposes, the steady campaign waged by the Archæological Survey against the destructive forces of man and nature was none too early. The blow of retrenchment has badly affected this part of the budget as well, but it is hoped that the funds absolutely essential for the preservation of India's priceless heritage will in future never be grudged by the Government and the legislatures. The variety and range of monuments on the face of this vast country is almost unlimited and with the opening of new sites and fresh excavations the task of the conservator gradually tends to widen. The problems that arise with the decay of stone and rock surface in the famous rock temples of Western India like Elephanta and others have just been brought to the forefront and the immensity of the task will be apparent when it is remembered that the effect of centuries of neglect has been made good. The condition of most of the monuments in and around the imperial cities of Delhi and Agra has been vastly improved during the last 25 years, and besides numerous structural repairs to the monuments endeavours have been made to provide a beautiful garden setting around each of the principal monuments. Altogether a sum of about one crore and twenty-five lakhs of Rupees has been spent during the quarter of a century on the preservation of monuments and this will give some idea about the improvements carried out in regard to this principal activity of the Archæological Survey.

Archæological Chemistry

An important feature of archæology in India has been the creation of the post of the Archæological Chemist, which has been in existence since the middle of 1917, when Mr. (now Khan Bahadur) Sana Ullah was appointed to the post and specially trained in England for this work. The chemical work done during these twenty years by him is summarized below :—

Treatment of excavated objects

For the cleaning and preservation of antiquities discovered at the excavations and in the Museums under the control of the Archæological Department, suitable scientific methods have been developed; the numbers of antiquities chemically treated since 1917 were as follows –Copper and its alloys, 15,646; iron, 3,658; lead, 1,042; silver, 867; gold, 504; terra-cotta and clay, 3,984; stone, 1,033; faience, 641; glass, 58; shell, 29; stucco, 258; plaster of Paris, 42; wood, 82; paper, 19; textiles, 523; paintings, 211; bone and ivory, 200; zinc, 1; miscellaneous, 82; Grand Total, 28,880.

Analysis of excavated objects

The numbers of various specimens examined or analyzed are:—Copper and its alloys, 220; iron, 15; lead, 10; silver, 8; gold, 8; terra-cotta and clay, 96; stone, 73; faience, 67; mortar, 26; glass and glaze, 85; paper-pulp, 3; paintings, 8; stucco, 1; water, 7; miscellaneous, 91; Grand Total, 718. Of these, special importance is attached to the chemical analyses of the various materials from the Indus Valley sites, glass and glazes from various sites, and decayed stone specimens from a large number of monuments. From his analyses, Mr. Sana Ullah has elucidated the composition and technique of the metal-work, glass, glazes, faience, mortars, pigments and a variety of other objects which were in use in India from the IVth millenium down to the medieval times. The analyses of specimens from various decaying monuments have helped in understanding the nature of the agencies which are responsible for changes going on in them.

Treatment of objects in Museums and at sites

At the Indian Museum, Calcutta, steps were taken to preserve the whole collection exhibited in the galleries, with the exception of stone sculptures and inscriptions, Khotan manuscripts and coins. The lead coins have been transferred to metallic cabinets (free from woodwork) after preservative treatment. The whole collection of bronze and iron antiquities at the Archæological Museum, Nālandā was treated, as also were the metallic antiquities at the Archæological Museum, Sarnath. Some of the sculptures at the latter institution were repaired and cleaned. The Archæological Chemist helped the U.P. Provincial Museum, Lucknow, by cleaning and preservation of a few copper plates and other antiquities. At the Delhi Museum of Archæology in Delhi Fort, the whole collection of Persian and Mughal paintings was elaborately mounted and preserved. The task of mounting and preservation of the Buddhist silk paintings recovered by Sir Aurel Stein at the Central Asian Antiquities Museum, New Delhi, was even more taxing and complicated, but was accomplished by the Chemist. In the Punjab, at the Central Museum, Lahore, which is under the Provincial Government, the Chemist carried out the fumigation of the collection of carpets

and other embroidered textiles, besides treating several metallic, stucco and wooden objects. But the bulk of the Chemist's work in this province was centred round the two great excavated sites of Taxila and Harappa. At the former he devoted years of his time to the cleaning, preservation and repairs of several hundreds of copper, bronze and iron antiquities at the Archæological Museum ; at the latter site he encamped for several seasons and carried out the preservation and repairs of the whole collection of metallic, stone and pottery antiquities. Similar work was done at the great site of Mohenjodaro in Sind, where the vast amount of pottery and metal antiquities including jewellery was cleaned by the Chemist and his assistant. At Sāñchī in Bhopal State, besides repairs of pottery and stone sculptures, a large number of metallic antiquities were cleaned. In the field of preservation of fresco paintings, which forms one of the most important branches of preservation work in India, Mr. Sana Ullah had the advantage of assisting the Italian expert, Professor Cecconi, in his work on the preservation of the frescoes at Ajanta. He himself later carried out preservation measures at Bagh in Gwalior State, where another important group of frescoes is situated.

Treatment of Ancient Monuments

A preliminary survey of a large number of monuments suffering from decay has been made. It has been found that the problem of the weathering of the stone monuments is beset with considerable practical difficulties as in other parts of the World. Most of these are suffering from the chemical action of rain water in conjunction with the gases of the atmosphere. Experiments have been carried out on certain monuments in order to render their exposed surface waterproof, by treatment with paraffin wax paste, but the beneficial effect has been only short lived. It is, therefore, necessary to repeat the treatment after a couple of years or so, which makes the cost thereof prohibitive. In fact, no proper waterproofing treatment has been found which will be reasonably cheap and remain effective for even a decade. Another important cause of the decay of monuments in India is the presence of soluble salts. These salts may be formed by the chemical changes which are going on in the stone itself, or may be derived from the soil below ; but in the coastal areas the sea-winds are responsible for the presence of sea-salts in the monuments situated there. In the Bombay Presidency, for example, the decay of the rock-cut temples has been proved to be due mainly to the action of sea-salts. It has, therefore, been decided to eliminate them by repeated washing with fresh water, or by the application of wet paper pulp which is taken off when dry. Since the cave temples are not exposed to the rains, any surface treatment which may be carried out inside will be lasting and can also be made sufficiently effective against further inroads of the sea-salts. This scheme, elaborated by the Archæological Chemist, has been carefully

examined lately by a special committee of technical experts and unanimously approved of by them. This is, in fact, the only practical and hopeful measure, which the Department has been able to evolve so far for the chemical preservation of some of the most important monuments in this country. Preliminary experiments have already been carried out at the Elephanta Island.

The monuments on which paraffin wax paste has been tried are: Udayagiri (Gwalior); Jaugada inscription, Orissa; Nanaghat inscription; Aśoka monument, Lauriya Araraj, Bihar; Aurangabad Mutiny monument, Kheri; Temples of Sibsagar, Assam and Jaina image, Barwani.

V. Epigraphy.

Advances made during the last quarter of a century in the researches and studies of Indian Epigraphy which constitutes one of the most important branches of archæology in India and one which supplies the best foundation of history and chronology are as great as varied. By means of the numerous important data, brought to light within this period, various missing links have been supplied, wrong views corrected, disputed points settled and fresh information added, so that our knowledge of the ancient history of India has improved considerably. Below are detailed some of the most salient advances in Sanskritic and Dravidian Epigraphy.

Edicts of Aśoka in Nizam's Dominions

The discovery in 1914-15 by Rao Bahadur Krishna Sastri of a Minor Rock Edict of Aśoka on the Maski Hill in the Nizam's Dominions deserves the foremost mention. This is the only record wherein the emperor's personal name *Aśoka* appears along with the title *Dēvānāṁpriya.* The various Rock and Pillar Edicts discovered in different parts of India mention only the title in Prakrit, which rendered into Sanskrit would be *Dēvānāṁpriyaḥ Priyadarśī rājā* and this king Priyadarśin was identified with Aśoka on the strength of the internal evidence of the inscriptions themselves and other literary evidence. The Maski Edict has confirmed the conjecture. It was again in the Nizam's Dominions that later (in 1930-31) two new versions of Aśoka's Minor Rock Edict were brought to light, one carved on the Gavimath rock and the other on the Pālkīguṇḍu hill, both near Kopbāḷ, some 54 miles south of Maski. One of them is completely preserved. They add no fresh information, but they present some points of linguistic interest.

Yerragudi Edict of Aśoka

Another Minor Rock Edict with an enlarged version, issued by Aśōka along with a set of his fourteen Rock Edicts was discovered (in 1928-29) on a small hill known as Eṇakoṇḍa near the village of Yerragudi (94 miles east of Kopbāḷ) in the Kurnool district of the

Madras Presidency. This is the only place where all the principal Rock Edicts have been found, along with the Minor Rock Edict. They, too, are interesting from the linguistic point of view.

Mauryan Inscription from Mahasthan

Of unusual interest is a short inscription in Mauryan Brāhmī, incised on a piece of hard limestone, which was discovered (in 1931) at Mahasthan in the Bogra District of Bengal. Its contents are similar to that of the well-known Sohgaura copperplate which was discovered many years ago and is of equally modest dimensions. Both the records seem to relate to some famine-relief measures undertaken by the State maintaining granaries for the purpose.

Ayodhyā Inscription

A brief but highly important Sanskrit epigraph, of the pre-Christian period, was noticed (in 1924) on a stone slab at the door of a temple at Ayodhyā. Herein we find for the first time mention of Pushyamitra, the founder of the Śuṅga dynasty that overthrew the Maurya supremacy. As in the Purāṇas so in the present inscription Pushyamitra is styled *Senāpati*.

Nagarī Inscription

Another remarkable lithic record in Sanskrit of about the same age was found (in 1934-35) in situ at Hathi-bada, a stone enclosure not far from Nagarī in the Udaipur State. It is remarkable that this document has reached us in triplicate, the other two copies (which must have originated from Hathi-bada) having been previously recovered (in 1915-16) in the same neighbourhood, one in a well at Ghosundi and the other in the outskirts of Nagarī. All the three are fragmentary, but fortunately almost the whole text has been restored, the missing portion of one having been supplied by the other. The record testifies to the prevalence at this early date of the worship of Saṁkarshaṇa and Vāsudeva, i.e., the two brothers Balarāma and Kṛishṇa of whom only the younger brother appears to have enjoyed the people's adoration in increasing measure. All the above inscriptions are written in Brāhmī characters and range in date from the third century B.C. to the middle of the second century B.C., the last two being the earliest known writings in Sanskrit.

Kharoshṭhī Inscriptions

The earliest known lithic record in Kharoshṭhī (except the Asokan Rock Edicts) has been brought to light recently from Bajaur, being on a relic casket of the time of Menander, the well-known Indo-Greek Buddhist sovereign, who lived in the second century B.C. Among other epigraphical discoveries which can be placed in the first century of the Christian era are certain dated records in the Kharoshṭhī alphabet from Taxila, namely the Kalawan Copperplate (discovered in 1931-32) and the Taxila Silver Scroll (found in 1913-14). The former record is dated in the year 134 and the

latter in the year 136, possibly of the same era. While it has not been quite settled as to which specific era is meant, Dr. Sten Konow is of opinion that it refers to the Vikrama Samvat. According to this the years 134 and 136 would correspond to A.D. 77 and 79 respectively. Both the inscriptions are Buddhistic and record deposit of relics by certain individuals. The later record mentions a Kushāna sovereign but does not state his name.

Brāhmī records of the Kushāna period

Quite a number of new inscriptions belonging to the Kushāna rulers have been discovered and, as usual, most of them are written in what is known as Kushāna Brāhmī, some few being written in Kharoshṭhī as well. Some of these records are dated and they refer to the Kushāna era, the initial date of which it has not yet been possible to fix definitely. The inscription engraved on a Bodhisattva statue in the Allahabad Museum is the earliest of this era, being dated in the 2nd year.

Silāhara cave inscriptions

Seven short inscriptions in the Brāhmī script of the first and second centuries A.D. were found (in 1927–28) in the caves at Silāhara in the Rewah State of Central India. Their language is Prakrit and they record the excavation of the caves by one Maudgaliputra Mūladeva of the Vatsa gotra, the minister (amātya) of king Svāmidatta about whom no further details are unfortunately available. Mūladeva is mentioned as son of Śivamitra, grandson of Śivadatta and great grandson of Śivanandin. As regards the king Svāmidatta, the celebrated Allahabad Pillar Inscription mentions one Svāmidatta as king of Koṭṭūra in Dakshiṇāpatha who was conquered by Samudragupta in the fourth century A.D., but the homonymous prince of our inscriptions must have lived in the first century A.D. While in two of these records the caves are called Silagaha (Skt. *Śilāgṛiha*, of which the modern Silāhara is probably a corruption), in another we have *ārāmaṁ pavate* which would mean 'pleasure-house on the hill'. From this the Silāhara caves seem to have been excavated for sportive and merry-making purposes. The two caves at Ramgarh, previously discovered, are of the same nature. All the other caves that have so far been discovered were intended to be religious edifices.

Kirari pillar inscription

A wooden pillar of considerable length, containing a fairly long inscription in Brāhmī characters assignable to the second century A.D. was dug up in 1921–22 from a dried up tank at the village of Kirari in the Bilaspur district of C.P. Fortunately an eye-copy of the inscription was prepared instantly by a local pandit, for the pillar after being exposed to weather cracked and peeled off thereby destroying most of the inscribed letters. The deciphered part of the inscription reveals a number of official designations that were in vogue in those days.

Nandsa inscriptions

A very remarkable discovery was made in 1927 at Nandsa in the Sahara district of the Udaipur State, in the form of a stone Yūpa (sacrificial post) which bears two inscriptions, both dated the Kṛita year 282. Their full contents have not yet been made known. One of them records the performance of the Shashṭhirātra sacrifice by one Śaktiguṇaguru. The term Kṛita occurs in certain previously known records as well and has occasioned much discussion, but now it is accepted to stand for the Vikrama Samvat. Unless the two Kharoshṭhī records mentioned above are also dated in this very era, the present one is the earliest known inscription dated in the Vikrama era.

Badva inscriptions

Recently (1935–36) three more Yūpas of the same type have come to light at Badva in the Kotah State, each bearing a short epigraph dated the Kṛita year 295. The group originally consisted of four such posts, but of the fourth only a fragment could be recovered. The three inscriptions pertain to three brothers, Balavardhana, Somadeva and Balasiṁha, sons of the Mokhari Mahāsenāpati Bala, and commemorate the performance of the Atirātra sacrifice by each separately. Many years ago Cunningham discovered a seal which had the legend *Mokhalinaṁ* in Brāhmī characters, but gave no name of the king. The present Yūpas are thus the earliest which make mention of any Maukhari chief.

Inscriptions of Ikshvāku dynasty from Nagarjunikonda

During the excavations carried out (in 1926 onwards) at Nagarjunikonda, another Buddhist site of great interest discovered in South India besides those already known at Amarāvatī and Jaggayyapeta, nearly fifty inscriptions on stone pillars and slabs were brought to light. Their language is a Prākṛit and the script Brāhmī of about the 3rd century A.D. They record gifts made to the Mahāchetiya (Skt. *Mahāchaitya*) and other religious buildings by certain queens and princesses of the Ikhāku (Skt. *Ikshvāku*) dynasty. Most of the inscriptions are dated. The known dates are the 6th, 14th, 15th, 18th and 20th years of the reign of the Ikhāku king Māḍhariputa Siri-Vira-purisadata (Skt. Māṭharīputra Śrī-Vīrapurushadatta) and the 2nd and 11th years of the reign of his son Vāseṭhīputa Siri Ehuvula-Chāṁtamula. We already know of this dynasty from three similar inscriptions discovered at Jaggayyapeta which are dated in the 20th year of the reign of the former king. The Nagarjunikonda inscriptions furnish us with such additional information. 'They mention not only Māḍhariputa Siri-Virapurisadata, in whose reign the principal sanctuaries of this locality were founded, but also his father, Vāseṭhiputa Siri-Chāṁtamula, and his son and successor Vāseṭhiputa Siri Ehuvula-Chāṁtamula. In a passage which occurs in several of the inscriptions, the former is eulogized as 'a performer of the Vedic

sacrifices Agnihotra, Agnishṭoma, Vājapeya and Aśvamedha.' The adherence to such Brahmanical rites on the part of this male member of the royal family and the devotion to the Buddhist faith on the part of the ladies of his house are points worthy of note.

The inscriptions, on stone, copper or any other material, discovered within the last 25 years, which range in date from the 4th to the 16th century A.D. are by far more numerous, and, as a rule, pertain to the dynasties already well known. The recent discoveries have no doubt greatly supplemented our knowledge of their history and chronology.

Mathurā inscription of Chandragupta II

A stone pillar was discovered (in 1928) at Muttra (Mathurā) which bears an inscription dated in the 61st year of the Gupta era. It belongs to the reign of Chandragupta II, son of Samudragupta. The Gupta year 61 corresponds to A.D. 380 and is the earliest date known of Chandragupta II, while his latest date so far known is the Gupta year 93. We have thus an evidence that this monarch had a reign of at least 32 years. The pillar in question contains besides the inscription also a figure identified as Lakulīśa, which if the identification is correct, is the earliest representation of this form of Śiva yet known.

Copper plate of a Vākāṭaka Queen

A copper-plate grant of the Vākāṭaka queen Prabhāvatīguptā was found (in 1912) at Poona. This record is of great value inasmuch as it has once for all put an end to much controversy and has thrown a decisive light on the Vākāṭaka chronology. It was known from certain other Vākāṭaka inscriptions that Prabhāvatīguptā was a daughter of Devagupta whose identity was not certain but who was believed by some to be a later Gupta ruler. The present grant has, however, left no doubt that Devagupta was another name of the Gupta sovereign Chandragupta II.

Inscriptions of Meghas

Two lithic records were noted (in 1935-36) in the Allahabad Museum, both dated in the year 87 of an uncertain era and belonging to the time of *Mahārāja* Bhadramagha. Two similar inscriptions were discovered (in 1921-22) at Kosam in the Allahabad District, of which one is dated in the year 88 and belongs to the time of the same ruler, while the other pertains to *Mahārāja* Śivamagha. The portion of this latter, containing the date, is damaged. It cannot therefore, be ascertained whether Śivamagha preceded or succeeded Bhadramagha as nothing is known of these rulers from other sources. They are held to be identical with the Meghas of the *Purāṇas*. The years 87 and 88 are suggested to pertain to the Kalachuri era which began in 248 A.D., as they are too early to be referred to the Gupta era, considering the peculiarities of their language, palæography and manner of dating as well

as the fact that in the *Purāṇas* the Meghas are said to have preceded the Guptas.

Gupta Copper plates from Bengal

Some copper plate inscriptions belonging to the 5th and 6th centuries A.D. have been discovered from North Bengal. They are not ordinary land-grants, but are typical sale-deeds and as such form a class by themselves. The individual—a commoner, an official or a subordinate prince—purchases a piece of land from the State for the purpose of bestowing it upon a religious person or institution, whereby customary formalities are observed by the State authorities. The procedure followed is found to be almost uniform in all the records. Usually various functionaries partake in these transactions. The designations of some of them as well as certain peculiar terms, such as of different land-measures prevalent in those days in that part of the country are pieces of new information furnished by these documents. Eight of these plates namely, five from Damodarpur, one from Dhanaidaha, one from Paharpur and one from Baigram, are dated in the Gupta era and belong to the Imperial Guptas of Magadha, four to the time of Kumāragupta I, three to that of Budhagupta and one to that of Bhānugupta (?). They are at the same time an evidence that North Bengal was also a part of the Gupta empire. Some other records of this type pertain to other sovereigns apparently connected with the Gupta dynasty, such as Vainyagupta, Dharmāditya, Gopachandra and Samāchāradeva, about whom more information is steadily accumulating from coins, seals, etc.

Inscription of Ghaṭotkacha-gupta

The name Ghaṭotkachagupta, as that of a member of the Imperial Gupta dynasty, was known from a seal found (in 1903-04) at Basarh (ancient Vaiśālī) in the Muzaffarpur District of Bengal as well as from a coin in the St. Petersburgh collection, but its identity was very uncertain. This uncertainty has almost been removed by the discovery of a stone inscription, a considerable portion of which is missing, at Tumain (ancient Tumbavana) in the Gwalior State. It is dated in the year 116 of the Gupta era and belongs to the time of Kumāragupta I. Its importance lies in that it mentions Ghaṭotkachagupta. The part stating his exact relationship with Kumāragupta I, is lost, but he is in all probability a son of the latter and is to be identified with the person of the same name appearing on the seal and the coin referred to above.

Nālandā Copper plate of Devapāladeva

A copper plate charter, found (in 1920-21) among the ruins of a monastery at the famous Buddhist site of Nālandā in Bihar, is of unusual interest inasmuch as it alludes to the friendly relations that existed between the Pāla rulers of Bengal and the kings of the islands of Java and Sumatra. It records the grant of five villages to a vihāra by the Pāla king Devapāladeva.

The monastery was built by Bālaputradeva, the Śailendra king of Suvarṇadvīpa (Sumatra), and the gift of villages was made at his request through an ambassador. Much has been known of the Śailendra kings from various inscriptions found in Java and Sumatra.

Irda Copper plate of a Kāmboja king

A copper plate grant of much historical importance, assignable to the 10th century A.D. was recently (in 1934-35) obtained from a Zamindar of Irda in the Balasore District of Orissa. It introduces us to a new line of kings, viz., Kāmboja *vaṁśa*. It records the gift of a village by the king Nayapāladeva of this family. The names Rājyapāla, Nārāyaṇapāla and Nayapāla of the Kāmboja kings found in this record are also borne by some of the Pāla kings of Bengal, which may cause a confusion, but a close examination has shown that the Pālas represent quite a distinct family and that they were succeeded by the Kāmbojas in North Bengal about the latter half of the 10th century A.D. The only other inscription that speaks of a Kāmboja king of Bengal is the one on a pillar from Bangarh in the Dinajpur District.

South Indian or Dravidian Epigraphy

Turning to Dravidian Epigraphy, which is a specialized branch of epigraphy, owing to the profusion of records and the linguistic peculiarities of the South, we find that its annals commenced nearly fifty years ago. In 1887, Dr. Hultzsch was appointed as Government Epigraphist to collect, examine and issue annual reports on the large number of inscriptions available in South India, where his headquarters were fixed. Dr. Hultzsch's 'Annual Reports on epigraphy' embodied the activities and studies of the Epigraphist and his staff, not only in relation to the inscriptions in the Dravidian languages but also in those of the Sanskritic and Prākritic languages, though the former on account of their enormous bulk and variety figured predominantly in these reports. With the retirement of this scholar in 1903, South Indian Epigraphy became even a more specialized study and the annual reports were more particularly related to Southern Epigraphy, though occasionally important inscriptions received from the north and composed in the Sanskrit and Prākṛit languages received their share of treatment. Ultimately in the year 1922, it was decided that the annual reports issued by the epigraphist in Madras should be styled 'Annual Reports on South Indian Epigraphy', although occasionally inscriptions connected with Northern Epigraphy were noticed in these reports.

During the quarter of a century ending with March, 1936, more than 6,000 villages were surveyed epigraphically in the Madras Presidency. As a result of this survey no less than 15,000 stone inscriptions were copied in the province and reported upon. About 330 copper plate inscriptions have also undergone examination during this period. The contributions that these numerous records

have made to our knowledge of ancient South Indian history, politics, economics, sociology and religion is too far-reaching and wide in its extent to be detailed here. A perusal of any of the Annual Reports dealing critically with these inscriptions will show what valuable additions to historical knowledge they have made. It may not be an exaggeration to say that all the historical theses from the hands of University Professors, scholars and research students that have appeared within the last two decades have drawn deep upon these fountain-heads of knowledge, together with the other useful series called *South Indian Inscriptions-Texts* and *Texts and Translations Series*, in which the inscriptions have been published *in extenso*.

Vēlūrpāḷaiyam copper plates

Coming to the discoveries actually made during the last quarter of a century, mention must first be made of the important set of Vēlūrpāḷaiyam copper plates belonging to the Pallava king Ko Vijaya-Nandivikramavarman which came to light in 1910. These have proved a veritable mine of information for the genealogy and history of the Southern Pallavas. The exhaustive treatment of this valuable document as also of another equally important record (viz., the Taṇḍantōṭṭam Plates of the Pallava monarch Vijaya-Nandivarman) make volume II, Part V, of the *South Indian Inscriptions* a very important publication. In the year 1912 attenion was drawn to a large number of Brāhmī inscriptions found in certain natural caves of the Madura and Tinnevelly districts which comprised the ancient Pāṇḍya country. The script employed in these is of the Asokan type but the language is not the Prākṛit of the Northern inscriptions of this period, but a mixed dialect composed of Prākṛit and Dravidian elements, the latter appearing for the first time in lithic records. Some scholars have, however, tried to make these out as purely Tamil inscriptions, but the view lacks wide support. That these epigraphs were associated with the sojourn of ascetics is evident from the proximity of rock-hewn beds found in some of these caverns.

Inscription of a Chola king; two Kaliṅga copper plates

An inscription brought to light in 1912 and belonging to the time of the Chola king Kulottuṅga II helped to assign Śēkkiḷār, the author of the Tamil work *Periyapurāṇam* to the middle of the 12th century A.D. Two important copper plate documents came to light at this period, referring themselves to two unknown Kaliṅga kings, Śaktivarman and Umāvarman, who appear to have ruled over the country round about Piṭhāpuram in about the 5th and 6th centuries A.D.

In the year 1912-13 at Nilagunda in the Harpanahalli taluk, Bellary district, was discovered an important copper plate grant belonging to the well-known Western Chālukya king Vikramāditya VI and dated in the 12th and 48th years of the era started by this sovereign and mentioning his two subordinates Palata-Pāṇḍya

and Rāya-Pāṇḍya, at whose request he made grants to some Brāhmans who immigrated into these parts from the Draviḍadeśa. The only copper plate grant hitherto known as belonging to the later Vijayanagara king Tirumala I was also brought to notice in this year. The examination of the several inscriptions of the great and ancient Ādhipurīśvara temple at Tiruvoṟṟiyūr near Madras revealed the eventful life of a Kerala Brāhmaṇa general called Chaturānana-Paṇḍita, who was very much favoured by the Rāshṭrakuṭa king Kṛishṇa III, though really a spy of the Chola king and an intimate friend of the Chola prince Rājāditya. For the infamy of not having fallen in battle together with his royal friend the general felt keen remorse, penitently renounced the world, received initiation and holy orders at the hands of the spiritual teacher Nirañjana-guru and, as a recluse, became the head of a *maṭha* attached to the temple and took interest in several improvements to the same. Incidently light is thrown on the fact that the mother of Kṛishṇa III made some donation to the temple.

Copper plates of Vikramāditya VI, Tirumala I and Tiruvoṟṟiyūr inscriptions

The year 1913-14 was momentous for the discovery of the early Western Gaṅga grant, the Penukonda Plates of Mādhava II (III). In Dr. Fleet's opinion this is perhaps the only genuine record of the early Gaṅgas of Mysore and 'A.D. 475 seems a very good date for it'. It has thus a great bearing on the history and chronology of this family, as also the other connected dynasties of the Pallavas and Kadambas.

Penukonda Plates

With this year a new and useful feature was added to the epigraphical report. The late L. D. Swamikannu Pillai who was an indefatigable student of astronomy and South Indian chronology voluntarily offered to append to the report every year a section embodying detailed calculations of dates appearing in the South Indian epigraphs reviewed therein, mainly based on his *Indian Ephemeris*, a monument of scholarly industry. After the demise of that scholar these calculations have been made by the departmental staff after the data supplied by the Ephemeris.

Astronomical calculations

The year 1915-16 was productive in that it brought to light an Āndhra (Sātavāhana) rock inscription at Myakdoni in the Bellary district. Two very important Pallava copper plates called 'Omgodu grants' were discovered in this year in the Guntur district. In 1916-17 a Brāhmī inscription of about the 1st century B.C. was noticed in the Buddhist cave at Guntupalle in the Kistna district, while in the same year was also discovered a very long and informative stone pillar inscription of the Kākatīya queen Rudramādevī at Mandadam in the Guntur district. Apart from the

Myakdoni inscription, Omgodu grants, Guntupalle and Mandadam inscriptions

solution it affords for certain genealogical problems connected with this queen, the record is very interesting in that it describes in detail the philanthropic activities of the great Śaiva-rājaguru, Viśveśvara-Śiva, who hailed from South-west Bengal (Dakshiṇa-Rāḍha). Among the several institutions provided for and maintained by this noble priest it is interesting to note the existence of a Maternity Home (Prasūty-ārogya-śālā).

Tamil inscriptions

In the year 1917-18 came to light several inscriptions in the Tamil districts which threw considerable light on the importance of the mediaeval South Indian temple as an educational institution and cultural centre. Another interesting discovery was that of an inscription containing eleven missing verses of the Tamil Śaiva religious anthology called *Devāram* and the epigraphical data incidentally enabling us to determine the date of this popular work in its present recension.

Gaṅga era

The year 1918-19 saw the find of six useful sets of Eastern Gaṅga copper plates from Chicacole, one of which is of inestimable value, as it furnishes the only available clue for definitely fixing the origin of the Eastern Gaṅga era.

Copper plates of Vishṇukuṇḍins and Dāmodara-varman

In 1919-20 a number of copper plates belonging to the short-lived dynasty of Vishṇukuṇḍins came to notice in the Guntur district. A more important discovery of the year was that of another copper-plate grant from the same district referring itself to king Dāmodaravarman of the Ānanda-gotra, who has palæographically been assigned to about the 4th century A.D. This forms a useful addition to the very few inscriptions of this period known so far.

Nala inscription

The year 1921-22 brought a very valuable discovery in the shape of the only known lithic record of the early family of Nalas of about the 5th century A.D. in the Agency tracts of Jeypore (Vizagapatam district). Though a set of copper plates belonging to this family came to light about this time, the stone inscription has proved to be of special value in locating the tracts over which the dynasty ruled.

Labelled portrait-statues; a Pallava-grantha inscription

Labelled sculptures in relief of the Pallava kings Siṁhavishṇu and Mahendravarman I found in the Ādivarāha cave temple at Mahabalipuram in 1922–23 have furnished us with contemporary portraits of these early monarchs of the south. A verse in Pallava-Grantha characters found in this locality, giving the names of the well known ten incarnations of Vishṇu (including Buddha) has been of value in suggesting the antiquity of this conception and the fusion of the Brahmanic and Buddhistic cults in this part of the country.

Alluru, Nagarjunikonda and Velpuru inscriptions

The discovery of a Brāhmī inscription of about the 2nd century A.D. at Alluru in the Kistna district, during the year 1923-24 brought to light a new Buddhist settlement in the Krishna-valley, where besides other well-known centres, such as Amarāvatī, Jaggayyapeta, and Bhaṭṭiproḷu, a Buddhist Stūpa was discovered at Ramireddipalle. But the most important event in South Indian archæology of recent years occurred in the year 1925-26, when the great Stūpa at Nagarjunikonda was discovered which next to Amarāvatī has turned out to be the most important and prolific Buddhist centre in the south. The numerous inscriptions and sculptures found here have furnished a link between its patrons the Ikhāku kings, and those of the Jaggayyapeta Stūpa, and thrown a flood of light on the history and art of this period. The same year also saw the discovery of the only known stone inscription of the Vishṇukuṇḍin dynasty at Velpuru in the Guntur district.

Kaliṅga copper plates, Pugalur inscriptions, etc

Among the important discoveries of the last decade may be mentioned the interesting copper plates of king Anantavarman and others who ruled over Kaliṅga about the 6th and 7th centuries A.D., the Brāhmī inscriptions at Pugalur near Karur (ancient Vañjimānagara), the South Indian connections of the Jain teacher Helāchārya who hailed from Hemagrāma (Tamil-Ponnur, North Arcot district) and some hitherto unknown early Ālūpa kings of the west coast, by name Yuddhamalla, Pulinnarasa, Āluvarasa, Nṛipamalla and Kandavarmarasa, whose dates range between the 7th and 9th centuries A.D. Buddhist ruins and rock-cut caves have been discovered at Korukonda in the Godāvarī district and Buddhist caverns and mounds at Nilavati and Nilayyavalasa in the Vizagapatam district. A hitherto unknown early rock-cut temple, probably the earliest monument of the Pāṇḍya country devoted to Śaiva worship was discovered in 1935-36 at Pillaiyarpatti in the Ramnad district.

Epigraphical Survey of Bombay Karnatak

An important feature of the activities of the Department during this period was the epigraphical survey of the Bombay Karnatak Districts. This was commenced in the year 1925-26 and the last ten years of the sustained effort have resulted in the inspection of 1,540 villages and the collection of about 1,600 inscriptions from this region. These are briefly reviewed in the *Annual Reports* and their publication in a dynastic and chronological form is engaging the attention of the Department.

Epigraphical publications

As regards the publication of the inscriptions of the Madras Presidency, only a few though very important parts of the original 'South Indian Inscriptions, Texts and Translations' series have been issued during the last quarter of a century. The last to be included in the

series are the valuable Pallava copper plate documents and the all-important Pāṇḍya copper plates called the Larger and Smaller Sinnamanur Copper Plates, which have been critically edited. In the year 1918 it was decided to discontinue the series and publish instead volumes containing the bare Texts of South Indian inscriptions, thus placing at the disposal of scholars a much larger mass of epigraphical material, which did not merit the exhaustive treatment given to them in the 'Texts and Translations' series. During the eighteen years that have since elapsed, Volumes IV to VIII of the South Indian inscriptions series embodying the texts of nearly 5,400 inscriptions in all have been edited and published. It was however found that scholars not familiar with the South Indian scripts in which the volume have been issued do not derive much help from these publications. It is now, therefore, arranged that further volumes in this series should be slightly different in plan, so as to facilitate such scholars, the purport of each record being given in a short introductory note in English. It is hoped that this series while expediting the publication will prove more useful to a wider circle of scholars than its predecessor. It has unfortunately to be recorded here that publication has not speeded up during recent years and at least five volumes, two for Kanarese and one for Telugu and two for Tamil inscriptions, have been delayed in process of printing owing to want of responsible scholarly officers, two out of three officers specializing in South Indian epigraphy having been retrenched in 1931.

Indo-Muslim Epigraphy

In the field of Indo-Muslim epigraphy, the progress achieved during the last 25 years is not inconsiderable taking into account the comparatively limited field. Fourteen numbers, including one 'Supplement', of the *Epigraphia Indo-Moslemica* have been published, and 568 inscriptions, belonging to different provinces from Kabul in the North-West to Dinajpur in the North-East and Mudgal (Raichur District) in the South have been dealt with. Chronologically they begin from the last quarter of the 6th century of the Hijra, about the time when Delhi was conquered, and come down to the 12th century Hijra when Moslem power became extinct in India. The inscriptions belong to various dynasties and by their wording and scripts represent the political strength, the cultural standards and the temperamental moods of these kings and their subjects. For example, the inscription of Muhammad Ibn Sam on the Quwwat-ul-Islam Mosque at Delhi, one of the earliest Islamic records in India, shows a sturdiness in its script and a religious fervour in its wording which are very characteristic of the feelings and temperament of that monarch, as will be apparent from the translation:

> 'This fort was conquered and this Jami Masjid built in the months of the year 587 by the Amir, the great, the glorious commander of the Army Qutb-ud-Daula waddin,

the Amir-ul-Umara Aibaq, the slave of the Sultan; may God strengthen his helpers. The materials (?) of 27 idol temples, on each of which 2,000,000 Deliwal had been spent were used in (the construction of) this mosque. God the Great and Glorious may have mercy on that slave, every one who in favour of the good (?) builder prays for this faith'.

The inscriptions of the Mughals on the other hand show a highly refined taste both in feeling and literary style, as for example in Akbar's *inscription* at Mandu, which runs thus :—

'Lo the owl hath built her nest
In Shirwan Shah's high storey,
Warning nightly by her cry,
Where now thy pomp and glory ?'

A similar spirit is noted when one reads the epitaph on the Princess Jahanara's tomb at Delhi :—

'Aught not but green grass cover my tomb
For it is pall enough for an humble spirit.'

The inscriptions of the minor dynasties of Bengal and the Deccan exhibited a highly ornamental style of writing, called the Tughra. The inscriptions of Husain Shah and Nusrat Shah of Bengal represent very good specimens of this style by their elaborate schemes and intricate designs. In the Deccan, owing to Iranian influence, the Thulth style of writing also was developed to a high level and the inscriptions of Bahmani Kings on the Madrasah of Mahmud Gawan or on the tomb of Hazrat Khalilullah at Bidar show much force and elegance in their design and technique.

The study of Moslem inscriptions has proved very useful in correcting the dates of important historical events such as battles or accession and death of kings. These records have also helped in fixing the boundaries of the empire of several kings, for example the extent of Muhammad Tughlaq's empire in the Deccan and the South, which is described in the haziest way in contemporary history, can now be fixed with certainty with the help of the inscriptions which have been discovered by the Archæological Survey.

Similarly the dates of the establishment of the various minor dynasties which sprang up at the disintegration of the Bahmani Kingdom have now been fixed with precision with the help of inscriptions and the doubts raised regarding them by historians have been satisfactorily removed.

The study of the Moslem inscriptions of India is thus being conducted on a scientific basis and the historical, literary and artistic aspects of the subject are receiving the closest attention.

VI. Numismatics.

Numismatics in India has made considerable progress during the last 25 years, which has been very recently summarized in

connection with the Silver Jubilee Supplement of the Numismatic Society of India which occurred in 1935. The Society started by a handful enthusiastic numismatists has now enlisted wide support among Indian numismatists, and is on a sound footing. In India numismatics has an important part to play in eliminating some of the darkest corners of Indian History. In the excavation of historic sites the association of coins with other antiquities, such as terra-cotta, pottery, etc., leads to the assignment of dates to antiquities and the different strata. In certain periods of Indian History, such as the history of Gujarat and Kathiawar in the 2nd to 4th centuries A.D., coins are the only available material for the reconstruction of the chronology of the Western Kshatrapas, who were rulers of the country.

Earliest Indian coins

The earliest coins in India are the punch-marked coins, the study of which has recently engaged the attention of a number of distinguished scholars and numismatists. Much light has been thrown during the last quarter of a century on the nature and sequence of the symbols and on the authorities, who must have been responsible for their issue during the long period through which they were current. The most important finds of these coins came from the excavations at Taxila where a large hoard of 1,167 silver coins was found in association with one Siglos of the Persian Empire and three Greek staters which were the issue of Alexander the Great and Phillip Aridaeus. Another hoard of 170 copper punch marked coins was found with a gold coin of Diodotus and some Mauryan jewellery. These finds have proved that the punch-marked coins were the main currency in the North-West in 4th and 3rd centuries B.C. when the Mauryan Empire was at the zenith of its power. The system of weights, the sequence of the symbols and other connected matters have been of late very carefully studied. It is plausible to conclude that the remarkably wide range of the occurrence of this class of coins which have been found from Peshawar in the North-West to Dacca in the North-East and have been known to occur in Hyderabad State and even in the Madras Presidency—is closely associated with the expansion of the Mauryan Empire. A large number of hoards from different parts of Bihar have been recorded during the last 20 years and this is quite in accordance with the fact that Bihar formed the hub of the empire. Each individual hoard has been carefully recorded, but not intensively studied, and it is yet too early to say whether the variations in the symbols are due to the different mints or to local authorities adopting a definite set of symbols, arranged in a particular order. An exhaustive survey of the punch-marked coinage will be found in Mr. Allan's recent Catalogue of Coins of Ancient India in the British Museum. Mention may also be made to the important work done by Mr. Durga Prasad in this

field and particularly to the excellent illustrations he has provided of the numerous symbols found on these coins.

Indo-Greek, Śaka and other coins

In the field of Indo-Greek and Śaka numismatics some advance has been made by the discoveries of a large number of coins and by the effort of individual numismatists such as Captain M. F. C. Martin. This scholar has brought to light and studied a considerable material pertaining to the little Kushāns and their contemporaries and successors in the North-West of India. Mr. Fardoonji D. J. Paruck has considerably advanced our knowledge of Indo-Sassanian coins and his monograph on the subject will for a long time continue to be the standard work on the subject. An important hoard of 363 coins found in the Rakha hills in Sinbhum District, Chhota Nagpur throw new light on the so-called Puri Kushān coins, inasmuch as one of the lot bears an inscription. The obverse of this type shows a human figure and a crescent and the reverse has three cones in arrow and the legend *ṭaṅka*, which is supported by 63 other specimens of the type from another hoard of coins from Balasore District, Orissa. Among the later Kushānas a new ruling chief Salonavira has been discovered by Rai Bahadur Prayag Dayal in a hoard of debased gold coins from Hardoi.

A new Āndhra king

Our knowledge of the Āndhra Kings has been advanced by the discovery of a new king Apilaka from a coin discovered at Balpur in Bilaspur and described by the writer. Certain new varieties of the known Āndhra kings have been described by Professor Altekar.

Tribal coins

Tribal coins which account for a good deal of India's currency during the early centuries of the Christian era have had some more additions to them such as Śibi-janapada coins discovered by Dr. Bhandarkar from excavations at Nagari near Chitorgarh. A very interesting discovery is that made by Dr. Birbal Sahni at the Khokra Kot Mound in Rohtak District, Punjab. Here were found clay moulds numbering over a thousand which contain the impressions of an important type of early Yaudheya coins (*circa* 100 B.C.) throwing important light on the method and technique of casting coins. The legend refers to the region named Bahudhānyaka of the Yaudheyas, which must be identified with South-East Punjab. Mention must here be made of the great work done by the late Dr. Jayaswal in elucidating many dark corners in the early history of India by throwing light on the readings and interpretations of coins of the early centuries of the Christian era.

Kshatrapa coins

In the field of Kshatrapa coins a considerable advance was made by the important hoards found during the last quarter of a century, the best known of which is the hoard numbering over two thousand from Sarwania in the Banswada State of Rajputana. Quite a number

of the existing gaps in the dates of the western Kshatrapa rulers have been completely filled up and very little uncertainty is now left in this branch of numismatics.

Gupta coins

In the Gupta period the publication of Mr. Allan's catalogue of Coins of the Gupta dynasty in the British Museum which appeared in 1914 constituted a great advance. Since then notable additions to the series continue to be made by various scholars including Sir Richard Burn, Mr. Panna Lal, Dr. Hirananda Sastri and others. Recently the name of a Gupta ruler named Vainya Gupta has been detected on some coins by Dr. D. C. Ganguly.

Coins of mediæval dynasties

Among the dynasties of the south, the Rāshṭrakūṭas are now for the first time credited with coinage, the ruler's name being Śubhatuṅga. The Yādava kings are now being definitely known to have issued some of the type of coins known as Padmaṭaṅkas. A large find of over 16,000 coins found at Kodur in the Nellore District, Madras, consists of Padmaṭaṅkas, issued by the Chālukyas and Yādavas, presenting interesting varieties. Another large hoard of the mediæval period is that of the 16,000 electrum coins found at Aunjhar in Banda District. These were issued by Lalitāditya, king of Kashmir in the 8th century A.D. and provide corroboration of the claim made for him in the Rājataraṅgiṇī that he occupied the Gangetic provinces.

Early Muslim coins

In the field of early Muslim numismatics considerable advance has been made, several catalogues and other smaller contributions having been published. Among the contributions of outstanding importance are Mr. Nelson Wright's Catalogue of the coinage and metrology of the Sultans of Delhi, which will long continue to be the standard work in the field. Important contributions have also been made by Mr. H. R. Nevill. The coinage of Malava and Gujarat has been further studied by Messrs. Singhal and Gyani and a large hoard of coins of the Bengal Sultans found in Dacca has been laid under contribution by Mr. N. K. Bhattasali. The coins of the Sultans of Madura have been studied by Mr. Shamsuddin Ahmad.

Mughal coins

In the field of Mughal numismatics much solid progress is noticeable, thanks to a number of important hoards of coins having been brought to light particularly in the United Provinces. At least 8 new mints have been discovered from these hoards and the collection of Provincial Museum, Lucknow, now claims to be the best with about 6,000 coins. Among the foremost scholars who have studied Mughal coins are Messrs. Wright, Whitehead, Brown, Sir Richard Burn and Professor Hodivala, the work of the last-named scholar entitled 'Studies in Mughal numismatics' standing out as an unparalleled

example of research in this branch, and a veritable mine of information dealing with problems of Mughal numismatics.

Acquisition by Treasure Trove

The private collector and enthusiast still continues to play an important part in the study of numismatics, but it is to the official examiner of Treasure Trove coins that an increasing measure of the work in this field is being gradually transferred. As many as 27 public collections are now supplied with treasure trove coins, and an idea of the vast material handled by official numismatists can be had from the fact that in the United Provinces alone, no less than 65,537 coins were examined during the last 25 years.

VII. Archæology in Indian States.

With the organization of the archæology in British India on a strong footing it was but natural that the principal Indian States should also devote attention to this subject, particularly as much of India's precious heritage is included within the domains of Indian Rulers. Several Indian States have now Archæological Departments of their own, and the work done in the States of Hyderabad, Mysore and Gwalior is as comprehensive as anywhere in British India as will be seen from the summaries given below. Besides this the States of Baroda and Jaipur have recently opened Archæological Departments of their own and been fortunate enough in securing the services of experienced archæologists from British India. This has already resulted in an appreciable advance and valuable discoveries have been made at Bairat in Jaipur and at several places in Baroda State. Travancore and Cochin, Mayurbhanj and Jodhpur have their own archæological services which have done a considerable amount of work. It is regretted that in the important State of Kashmir, which is one of the biggest and archæologically most important States the excellent work done in the first fifteen years of the period under review which includes the important discoveries at Avantipur and Hushkur should have been discontinued.

Hyderabad.—In the premier State of Hyderabad, the enlightened Government of His Exalted Highness the Nizam founded the Archæological Department in 1914, and ever since its establishment it has been its aim to preserve the monumental antiquities of the State on the one hand and to explore and excavate historic as well as pre-historic sites on the other hand. *Pari passu* with these objects the Department has also tried to collect and systematically arrange and exhibit in the Hyderabad Museum the movable antiquities, such as sculptures, inscriptions, manuscripts, paintings, coins, arms, fabrics, ceramics, metal work and wood and ivory carvings.

Treatment of Ajanta frescoes

The problems which faced the Department in the early years of its existence were by no means easy of solution. The very first problem was the preservation of the world-famous frescoes of Ajanta which were in an advanced stage of decay. The clay plaster (*rinzaffo*) on which the colours were originally laid, had become loose by climatic effects, as well as by the development of pests therein, and was gradually falling off from the rock surface; the colours had been dimmed by dirt and smoke, that had settled on the paintings through the neglect of centuries; lastly, the frescoes were further darkened by the varnish which some injudicious artists in comparatively recent times had applied to the paintings in order to brighten their details, without first taking the trouble of cleaning the painted surface. In order to solve these problems in a successful manner, the Department consulted experts all over the world and ultimately with the help of the late Lord Curzon and Sir Rennel Rodd, the British Ambassador at Rome, secured the services of two Italian *restaurateurs* to treat the frescoes in a scientific manner. The Italian experts worked at Ajanta for two seasons, (1920-21 and 1921-22) and their efforts in conserving the frescoes proved eminently successful, so much so that paintings which before conservation were apt to turn into dust at the gentlest touch are now as hard as stone and it is hoped will last for centuries to come. It may not be out of place to refer here to the methods and the chemicals used by the experts in conserving the frescoes. In cases where the cavity between the painted layer and the rock bed was not large, casein mixed with a little white arsenic has been injected in order to stop the growth of insect pests. Where however the cavity was large enough to admit of the insertion of thicker material Plaster of Paris has been used. Before starting their fixing operations, the experts first strengthened the painted surface with shellac diluted in alcohol and put on bandages of cloth with a view to avoid the danger of the paintings crumbling or peeling off from the rock-wall in the process of injecting the casein or Plaster of Paris. After strengthening the painted surface, the rock-wall was thoroughly cleaned with an air pump, in order to ensure the complete removal of destructive elements from the *rinzaffo* and the rock-bed, as also to secure a better adhesive effect for the substances which were subsequently injected.

In treating the decayed edges of the frescoes the experts have inserted round the edges a neat fillet of Plaster of Paris mixed with portland cement and powdered rock. The proportions in which the above materials were mixed are as follows :—Plaster of Paris 10 to 15% : Portland cement 40% : Powdered rock 50%. For the removal of the varnish previously applied the experts used alcohol, but to counteract the injurious effects of this substance a wash of spirit of turpentine was applied as a fixative immediately after the varnish had been taken off. Ammonia was found most

useful for removing the dust and smoke, but to remove the white patches which appeared on the painted surface after the use of Ammonia, the experts have applied a very light coat of French polish on the frescoes.

Conservation of monuments

Apart from the preservation and cleaning of the frescoes a vast programme of conservation has been carried out to stop the further deterioration of the rock-hewn shrines of Ajanta, Ellora, Aurangabad, Pitalkhora, Ghatotkach, Dharashva and Bhokardan, the last-mentioned place being a recent discovery of the Department. The shrine here belongs to the Brahmanical faith, having been built in the 8th century according to an inscription carved on a pillar. In the process of cleaning and examination new chambers and floors have been found at Ajanta and Ellora and a new hall at Ghatotkach. In preserving these monuments, the Department has availed itself of the most up to date methods, materials such as cement and steel largely taking the place of lime and stone, which were previously used. The result has been eminently successful, both from the technical and artistic points of view. For instance, to save the rock-porch of the great monolithic temple of Kailasa at Ellora by masonry props and buttresses would have been not only a difficult task, but the result would have been very unhappy, marring the beauty of the monument. By a judicious use of ferro-concrete, however, the frame set up by the Department for the support of the disintegrated masses of rock is so concealed from the eye, and even in places where it is visible so matches the colour of the weathered rock, that the visitor notices no incongruous feature in the general appearance of the monument.

The number of Brahmanical shrines conserved by the Department since its establishment is very large, the most notable among them being the temples at Anwa (Aurangabad District), Dichpalli (Nizamabad District), Hanamkonda, Ramappa and Ghanapur (Warangal District), Pillalmari and Pangal (Nalgonda District) and Ittagi and Alampur (Raichur District). All these monuments have been made structurally sound; their interiors have been thoroughly cleaned and tidied up, and such of them as had no enclosure walls have been provided with this external protection against intruders. The architecture of these monuments has also been carefully studied and described either in the *Annual Reports* of the Department or in a series of separate monographs which has been instituted.

The Moslem monuments of the Dominions have received an equal amount of attention regarding their preservation and study. Several of these rank high among the Moslem monuments of India, for instance, the great mosque of Gulbarga and the Bahmani mosque of Bidar—the architecture of both being characterised by a beauty of line in the arrangement of component parts, which are, however, of the simplest design. Among other edifices of the

Muhammadan faith, mention should be made of the Madrasah of Mahmud Gawan of Bidar and the Badshahi Ashur Khana of Hyderabad. These two buildings were apparently designed by Persian architects, for the Madrasah of Bidar has a strong resemblance to the Madrasah of Isfahan while the tile work on the walls of the Badshahi Ashur Khana is copied either from the Shiite shrine of Meshhad or from the buildings dedicated to the same faith in Iraq. The exquisite tile work of the latter monument has been thoroughly preserved and its roof has been re-constructed for the timber of the original structure had completely decayed. At the Madrasah Mahmud Gawan, extensive measures have been carried out to repair the building in such a manner as to restore it to some semblance of its pristine beauty. Other Moslem monuments which have been tended with care are the Bahmani tombs of Gulbarga and Bidar, the Baridi mausolea at the latter place, the Adil Shahi tombs at Gogi in the Gulbarga District and the Qutb Shahi tombs at Golcanda. In repairing these monuments the Department has not only made them structurally sound, but has improved their surroundings by laying out courts and removing all modern excrescences.

Inscriptions

Since its inauguration the Department has also discovered a very large number of inscriptions—three of which being the Asokan edicts are in Brāhmī and the rest in Sanskrit, Canarese, Telugu and Marathi. These records have been carefully edited and published in the series of Memoirs of the Department. Of these Memoirs, 12 have already appeared and the thirteenth dealing with the Telugu inscriptions of the Dominions *in extenso* is now in the press.

Exploration of sites

The claims of existing monuments being so pressing, it was not possible for the Hyderabad Archæological Department to devote regular attention to the exploration of sites during the first two decades of its existence, although a number of sites of the early stone age and iron age were discovered, tombs and cromlechs were systematically opened up and a large amount of pottery with incised markings was unearthed. Recently a site near Maski, the provenance of the Aśoka rock edict, was excavated and the find of pottery and beads associated with a microlithic culture gives the hope that the Deccan plateau will also yield as valuable material for the reconstruction of India's hoary past as the valley of the Indus has done.

Hyderabad Museum

In pursuance of the policy of providing for the dissemination of knowledge, side by side with scientific research, His Exalted Highness the Nizam's Government, established a Museum in Hyderabad in 1931. It has separate sections for Sculpture, Painting, Old Arms, Ceramics, Textiles, Coins and Bidri-ware. Although this is one of the latest additions to India's Museums, some of its sections

compare favourably with those of more senior and long-established institutions in this country.

Mysore.—The formation of a regular Archæological Department in Mysore dates back to 1890 when Mr. B. L. Rice guided its work down to 1906, and carried out an enormous programme of work which earned for the department considerable fame. The most important task conducted by this scholar was an epigraphical survey of the State, in course of which nearly 10,000 inscriptions were published in the twelve volumes of the *Epigraphia Carnatica.* Among his discoveries are included many famous inscriptions like the Siddapur rock inscription of Aśoka. The net results of his labours is collected together in a small volume known as 'Mysore and Coorg from the inscriptions'. The result of his studies in the field of archæology and Numismatics was published in the Mysore Gazetteer.

Epigraphical works

Mr. Rice was assisted in his epigraphical work by Mr. R. Narasimhachar, who succeeded him as the head of the Archæological Department in the year 1906. During the sixteen years of his tenure Mr. Narasimhachar was able to collect about 5,000 inscriptions more and to publish a revised and enlarged edition of the Inscriptions of Sravana Belgola. A few of the more important of his discoveries have been published in the Annual Reports of the Mysore Archæological Department. But the greater part of the inscriptions collected by him was left in various stages of preparation for being published in a series of supplementary volumes to the Epigraphia Carnatica. Among his most important discoveries may be mentioned the Kudlur grant of Mārasiṁha, the Manne plates of the Gaṅga king Rājamalla I, the Gummareddipura plates of Durvinīta, the stone inscriptions of Śivamāra and Nītimārga at Talkad, the Nandi plates of the Gaṅga king Mādhava I and of the Rāshṭrakūṭa king Govinda III and the Bendiganahalli plates of the Gaṅga king Vijaya-Kṛishṇavarman.

Study of monuments, manuscripts, coins and inscriptions

Mr. Narasimhachar's reports also contain brief notices of the various architectural monuments inspected by him as also of the coins and manuscripts which he studied. He published three short monographs on the Hoysala temples of Somanathapur, Belur and Doddagaddavalli. Perhaps the greatest service he rendered to the scholarly world was in the field of Kannada. He not only brought out an authoritative edition of the famous old Kannada grammar, the Śabdānuśāsana, but produced and published a highly authoritative history of Kannada literature based on the study of thousands of manuscripts.

Dr. Shama Sastry who succeeded Mr. Narasimhachar as Director of Archæology not only commenced to publish the epigraphical finds of each year in the Annual Reports but also continued to publish notes on the literary works and the

architectural monuments studied by him and his assistants. Among the several records discovered and edited by him may be mentioned the Gaddemane inscription of Śilāditya, the Chukuttur grant of Simhavarmā, Kodanjevarum grant of Avinīta, the Hebbata grant of Vishṇuvarmā and the Kovalevettu plates of Srīpurusha.

The Ancient Monuments Preservation Regulation was passed by the Government of Mysore and after a few years of experiment the duty of conducting periodical inspections of the monuments, etc., was transferred to the office of the Consulting Architect to the Government of Mysore. The chief conservation work done during his régime was the renovation of the famous temple of Keśava at Somanathapur.

In 1928-29 Dr. Shama Sastry was succeeded by Dr. M. H. Krishna, who after his return from special training at the University of London was made the head of the Archæological Department in addition to his own duties as a professor of History in the University of Mysore. Dr. Krishna commenced to issue a new series of the Annual Reports of the Department. Over a thousand inscriptions have been copied since 1929. The inscriptions collected every year have been published in these reports with translations for most of them and detailed notes on the more important. Among the chief discoveries made by him the following may be mentioned :—Chandravalli inscription of Mayūraśarman; the Pandurangapalli plates of Avidheya Rāshṭrakūṭa ; the Keregalur and other copper plates of the Gaṅgas ; Devarahalli stone inscription giving the genealogy of the Gaṅgas ; Koramanga grant of the Kadamba king Ravivarmā ; Palmidi stone inscription of the Kadamba king Mṛigeśa, which is the earliest known inscription in Kannada.

The first part of the Index to the Epigraphia Carnatica has been published as also an index to the Annual Reports from 1906 to 1922. The inscriptions collected by Mr. R. Narasimhachar, which number nearly 5,000, are being prepared for publication in the Supplementary Volumes to the Epigraphia Carnatica.

A collection of about 5,000 coins belonging to the Government of Mysore has been studied in detail and a catalogue prepared. The main results of this numismatic study have been published in the Annual Reports of the Archæological Department.

Excavations at Chandravalli, etc.

At the suggestion of Sir John Marshall the excavation of the ancient site of Chandravalli was taken up in 1929 and conducted for three very short seasons. More than 5,000 objects were recovered and catalogued. But owing to financial difficulties the work was stopped. A monograph on the excavation thus far conducted is in the course of preparation. Trial excavations have also been conducted in Brahmagiri. The mounds close to the Rock Edict of Aśoka have revealed the existence

of about four inhabited layers—the topmost indicating the existence of a Chalukyan town, the second of the ruins of the Asokan Isila, the third of a prehistoric Iron age town and the last of a stone age settlement of the microlithic period. Over twenty other ancient sites have been surveyed and marked out for excavation in the State. Mysore is specially rich in her architecture. A detailed survey of the ancient monuments of the State was begun in 1929 and a large work on the monuments of Mysore has been prepared with numerous drawings and photographic illustrations.

Conservation of Halebid and Belur

The conservation of a large number of ancient monuments was taken up, special attention being devoted to the great monuments of Halebid and Belur. The latter have been scientifically renovated, more than Rs.50,000 being already spent for the purpose.

Museum

An archæological museum has been started at Mysore and it is proposed to expand it into a representative museum of antiquity and fine arts in the near future.

Gwalior.—The territories of the Gwalior State have a fair share in the wealth of ancient monuments covering a period exceeding two thousand years. Under the inspiration of Sir John Marshall, the then Director General of Archæology in India, His Highness the late Maharaja Sir Madhav Rao Scindia of Gwalior instituted, in October 1913, an Archæological Department to explore and preserve the precious relics of the ancient art and culture in his State. Mr. M. B. Garde who has had the privilege of completing his training in Archæology under Sir John Marshall was entrusted with the work of organizing the new Department and he has been in charge of the Department ever since. It will be seen that the work, accomplished by the Department during the last 24 years of its existence as summarized below, constitutes a model for other Indian States.

During the first few years from its inception, the Department was engaged in exploring and cataloguing the Archæological monuments in the State, which include a large number of ancient sites, buildings, sculptures and inscriptions previously unknown and new light was thrown on many an imperfectly known monument. Among the important ancient sites identified in the course of the exploration are Padmāvatī, Tumbavana and Devagiri.

Padmāvatī

Padmāvatī, one of the capitals of the Nāga kings who flourished in the 3rd century A.D., is vividly described by Bhavabhūti in his famous play the *Mālatī-Mādhava*, the scene of which is laid in the city. The place also appears to have possessed a University which attracted students from far off lands. Coins, brick foundations and other relics referable to the early centuries of the Christian era have been

traced here. Padmāvatī was variously identified by scholars. A close observation of the surface indications of the village Pawaya situated on the confluence of the rivers Sindh and Parvati, about 45 miles to the North of Gwalior, and its geographical environments led to its identification beyond doubt as the site of the ancient city of Padmāvatī, and trial excavations carried out later on corroborated the conclusion.

Tumbavana

Tumbavana is mentioned in the Buddhist Literature as a stage on the old road from Śrāvastī to Pratishṭhāna and is also referred to in some of the votive inscriptions on the railing of the great Stūpa at Sāñchī. A Gupta inscription mentioning the ancient name of the place, and a number of sculptures and other relics of the Gupta and mediæval periods found at Tumain, a village in the Esagarh District, made it possible to establish its identity with Tumbavana.

Buddhist monuments

Coming to discoveries of monumental antiquities, remains of Buddhist Stūpas were discovered at Bigan and Gyaraspur (*circa* 6th century A.D.) in the Bhilsa District and a rock-cut Buddhist *vihāra* consisting of a series of cells excavated in the crescent shaped face of a hill was discovered at Khejria Bhop in the Mandasor District.

Hindu, Jain and Muhammadan monuments

Numerous Hindu monuments including temples, and *maṭhas* or monasteries, the latter a very rare feature, have been brought to light within the Gwalior State. These include two shrines at Makhanganj (6th century A.D.), two Śiva temples at Mahua (7th century A.D.), the temples at Surwaya, Padhavli, Terahi, Kadwaha, Jamli and Khor (10th–11th centuries A.D.), the brick temple at Kherhat (10th century A.D.), the Toraṇa gateways at Terahi and Tumain (10th century A.D.), two-storeyed Śaiva monasteries (*maṭhas*) of the 9th-10th centuries—rare specimens of plain but massive stone architecture—at Surwaya, Terahi, Kadwaha and Kundalpur. Jaina temples of the mediæval period ranging in date from the 9th to the 15th centuries were brought to light at Padhavli, Suhania, Barai, Panihar, Narwar, Sesai Bhimpur, Indor, Golakot, Pacharai, Rakhetra, Bithla, Thoban, Tumain, Gandhaval and Nimthur. Among the discoveries of notable Muhammadan monuments mention may be made of the Koshak Mahal (a four-storeyed palace in the Mandu style) at Fatehabad near Chanderi, a Mughal mosque and a mansion at Udaypur, and a fine mosque at Bhonrasa.

Memorial stones and pillars

An interesting class of monuments that were listed are the inscribed *sati* stones and memorial pillars commemorating the self-immolation of widows and the death of warriors who lost their lives on battle-fields. The oldest of these memorial pillars (6th century A.D.) was found at Hasalpur. Another interesting memorial pillar

of the 7th century at Terahi commemorates a warrior killed in a battle with the Karṇāṭas or Southerners. Memorial pillars of the 9th and 10th centuries were found at Sakarra, Gadhi Barod, Padhavli, Badoh and other places.

Epigraphical and numismatic works

Epigraphical discoveries of historical importance comprise the Mandasor stone inscription of Govindagupta and Prabhākara (M.E. 524), the Tumain stone inscription of Kumāragupta and Ghatotkacha-gupta (G.E. 116), the Bagh copper plate grant of Mahārāja Subandhu of Māhishmatī (6th century A.D.), the Terahi memorial pillar inscription referred to above, the Mahua Mahādeva temple inscription of Vatsarāja (*circa* 7th century A.D.), the Gyaraspur and Maser fragmentary inscriptions (*circa* 10th century A.D.), the latter half of the Udaypur Praśasti, the Amer inscription of Paramāra Naravarman (V.S. 1151), Jeeran inscriptions of Guhilas and Chāhamanas (11th century A.D.), the stone inscriptions of Kachhapaghātas at Tilori and Naresar (11th–12th centuries A.D.), the Kuretha copper plate inscriptions of the Pratīhāras, the Chanderi stone inscription of the Pratīhāras (13th century A.D.), the numerous stone records of the Jājapellas (Yajvapālas) of Narwar (13th century A.D.) found at various places in the neighbourhood of Narwar, the memorial pillar inscriptions at Bangala which record a fierce battle fought between Gopāladeva, a Jājapella king of Narwar (Nalapura) and Vīravarmmadeva, a Chandella king of Bundelkhand (Jejābhukti) in V.S. 1338, and numerous other records of lesser importance.

To the above may be added numerous Hindi and Persian inscriptions of the Muhammadan period referring to the early Sultans of Delhi, the Sultans of Malwa, and the Mughal Emperors of Delhi.

Among the notable discoveries and acquisitions in the field of numismatics mention may be made of interesting punch-marked coins and Kārshāpaṇas excavated at Besnagar, Nāga coins from Pawaya and two other places which include the issue of hitherto unknown kings, e.g., Vṛisha Nāga, Puṁ Nāga, and Bhava Nāga.

Excavations

Trial excavations were carried out by the Department at Besnagar (ancient Vidiśā), Udaygiri, Mandasor (Daśapura), Pawaya (Padmāvatī) and Gyaraspur. No large buildings worth conservation were unearthed but selected small antiquities such as terra-cotta figures, pottery, inscribed seals, iron implements, beads and punch-marked coins recovered from the excavations have been exhibited in the Archæological Museum at Gwalior.

Conservation

When the listing of monuments had been well-nigh completed, the next stage in the work of the Department was reached when the scheme of conserving the more important of the explored monuments was sanctioned in the year 1920, the budget grant of the Department was revised

and the staff strengthened to meet the new responsibilities. The conservation work was commenced in right earnest in the year 1920-21 and during the last 15 years the following important monuments were conserved :—

The temples at Suhania and Padhavli, the Gujari Mahal Palace at Gwalior, the tomb of Muhammad Ghaus, the tomb of Tansen (the Orpheus of India), the temples and monastery at Surwaya, the monastery at Ronod, some palaces and mosques on the fort of Narwar, Koshak Mahal at Fatehabad near Chanderi, the rock-cut gateway, the Jama Masjid, and the tombs Bada Madarsa and Shahajadika Roza at Chanderi, the Gadarmal temple, the Solah Khambhi hall, the Dasavatara, the Satmadhi shrines and the Jaina temple at Badoh, the great Udayesvar temple at Udaypur, the Heliodoros pillar at Besnagar, the rock-cut caves at Udaygiri, the Bija mandal mosque at Bhilsa, the astronomical observatory at Ujjain, the Yaśodharman pillars at Sondni near Mandasor, and the temples at Gyaraspur, Khor and Kherhat.

The Buddhist caves at Bagh, well known for their wall paintings rivalling those at Ajanta, had fallen into a sad state of decay. Many of the caves in this group have hopelessly collapsed. Four of these which were capable of being reclaimed were freed from the enormous mass of their own debris with which they had been choked. New masonry pillars were constructed in place of old decayed columns to support the over-hanging portions of the ceilings. Wooden shutters were provided to protect the surviving fragments of the wall paintings which were fast fading away, being exposed to weather and rain. The paintings have also been faithfully copied to full scale both in colour and outline, and the copies exhibited at the Archæological Museum at Gwalior. Last year the representatives of the Harvard University and the Fogg Art Museum (U.S.A.) copied the paintings with the mechanical process of photography and it is proposed to publish the copies in a book form.

All monuments conserved are inspected periodically and maintained in good order. Caretakers and guides are kept at important centres of monuments. Approach roads have been constructed and rest houses built where necessary for the convenience of visitors to monuments.

Museum

The Archæological Museum maintained by the Department has established its reputation as one of the well kept Museums of its kind in India. The Museum is located in the Gwalior Fort, the collections being housed in the Gujari Mahal, itself an archæological monument of the 15th century. It was opened in 1922 and consists of a spacious open courtyard surrounded by numerous small rooms, in 22 of which the collections are accommodated. These rooms are open to the courtyard, save in the case of rooms Nos. 3 and 13 which contain pictures and small antiquities, and have been fitted with doors.

The collections comprise excavated pottery, terra-cottas, beads, relic caskets and iron implements, coins, inscriptions, capitals of pillars, images, railings and architectural pieces ranging in date from the 2nd century B.C. to the 17th century A.D. The Śuṅga, Gupta and mediæval periods are well represented and the exhibits are principally Brahmanical and Jaina. The Museum is particularly rich in Brahmanical images which represent most of the principal gods and goddesses of the Hindu Pantheon. Some of the sculptures are beautiful works of plastic art and a few are such as have not been found anywhere else, e.g., the stone palm capitals. Reproductions of nine of the Bagh frescoes occupy one room and another room contains a number of paintings of the Mughal and Rajput schools and large photographs of important archæological monuments in the State.

Popularizing archæology

Hand in hand with the foregoing activities, it was also thought desirable to educate the public to appreciate and respect the wonderful relics of ancient art and architecture of their country and to make monuments better known and attractive to the travelling public. To meet this manifold object the following measures have been devised and are being gradually put into practice as the necessary funds and opportunities become available:

(1) Descriptive Notice Boards are put up near every important conserved monument.

(2) Stone boards are put up at Railway Stations and on motor roads, calling the attention of travellers to important archæological monuments in the neighbourhood.

(3) Views of interesting archæological monuments are exhibited in Railway carriages, at Railway Stations, at Hotels and at Travellers' Bungalows.

(4) Descriptive notes on monuments and places of archæological interest in the State are contributed for incorporation into well-known Travellers' Handbooks and in Railway publications.

(5) Illustrated articles on monuments are contributed to Journals.

(6) The Department holds periodical 'At Home' parties generally in the premises of the Museum, when guests are shown round and entertained to a magic lantern show and lecture, thereby bringing them into touch with the activities of the Department.

(7) Lantern lectures are delivered at other suitable gatherings at headquarters and in the districts.

(8) Annual Reports of the Department, illustrated Guide Books, Albums, pamphlets and picture post cards are published and sold at nominal prices.

Publications

The following publications have been brought out so far: (1) Archæology in Gwalior; (2) The Bagh Caves; (3) The Gwalior Fort Album; (4) An illustrated Guide to the Archæological Museum at Gwalior; (5) A

Guide to Chanderi; (6) Sightseeing at Gwalior; (7) A Hand-Book of Gwalior; (8) Surwaya Album; and (9) Directory of Forts, Part I. Of these the monograph on the Bagh Caves is the most important. It contains coloured reproductions of some of the wall paintings on the caves and is a joint publication of the Gwalior Archæological Department and the India Society, London.

VIII. Publications.

Annual Reports, Memoirs and Imperial Series

The publications of the Archæological Department consist of a number of serial publications besides occasional monographs, guides, hand-books and catalogues of ancient monuments and museums. The most important publication which contains a complete record of all the activities of the Department is the Annual Report. At first this consisted of two parts, Part I being devoted to routine work and administration and Part II containing special articles, which was more important and bulkier than the other part. This arrangement continued until the year 1915-16 when Part II was abolished. Thereafter the material comprised in Part II of the report was transferred to the series of Memoirs of which 52 have been published up to date. They cover a wide range of subjects connected with every branch of ancient history and archæology. Part I of the report was abolished from 1920-21 and was replaced in the next year by a single volume of the Annual Report containing a full account of the work under conservation, excavation, epigraphy, museums and other branches of the survey. The present year has seen two Annual Reports, one covering the activities of 4 years ending 1934 and the other of the year 1934-35. The third series is known as the New Imperial Series in which monographs of great length requiring specially exhaustive treatment and a large number of illustrative plates have been published.

Epigraphical texts

The remaining four serial publications are concerned with the epigraphical branch. The most important epigraphical journal, *Epigraphia Indica*, is issued every quarter and exhaustively deals with inscriptions on stone, copper, etc., which have mainly helped scholars to build up the frame-work of Indian History of the pre-Muhammadan period. Indo-Muslim inscriptions are dealt with in the *Epigraphia Indo-Moslemica*, a biennial periodical, which has thrown important light on Indo-Muslim History and culture. South Indian Epigraphy accounts for two of the regular publications, namely, Annual Report on South Indian Epigraphy and the South Indian Inscriptions (Text series) in which the epigraphs are published *in extenso*.

Guide Books

A series of guides to important places of archæological interest, such as the Qutb, Delhi Fort, Agra Fort, Fatehpur-Sikri, Sarnath, Elephanta, Nālandā,

Hampi and last but not the least important—to Sāñchī and Taxila, have been issued by the Department. For the Indian Museum at Calcutta, a series of guides have been projected of which two have already been issued.

Non-departmental publications

Besides the publications of the Archæological Department a large number of periodicals and journals are published by private societies and individuals. The remarkable growth of studies in Indology during the last quarter of a century—thanks to the interest created by the establishment of a chair of ancient history and culture in the Calcutta University in the first instance and then in Benares, Madras and other universities—has been responsible for the phenomenal development of periodical literature in archæology, both in English and in the vernaculars, so that it is impossible for any single scholar to cope with the vast and growing materials. Mention must here be made of the excellent services rendered to the students of archæology by the Kern Institute at Leyden under the direction of Professor J. Ph. Vogel, who has been instrumental in bringing out an exhaustive Annual Bibliography of Indian Archæology during the last ten years.

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PROGRESS OF ANTHROPOLOGY IN INDIA DURING THE PAST TWENTY-FIVE YEARS.

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CONTENTS.

I. INTRODUCTION.

The past twenty-five years in Indian Anthropology, marked the end of a period, which occupied itself with a preliminary survey of the tribes and castes of India,—and the beginnings of the inauguration of more intensive studies of special groups of races in selected areas. In a wider sense, of course, the first traces of such studies go back to the time of the *Dharmasutras* when the ancient Brahminic law-givers in their efforts to regulate and regularise social conduct, attempted to associate different cultural elements with different peoples. Modern research in Anthropology, however, dates from the foundation of the Asiatic (now Royal) Society of Bengal by Sir William Jones in the latter part of the eighteenth century. The importance of collecting data on the habits and customs of the people was early realised by the members of the Society, and to this we owe the publication of many interesting papers, the most outstanding of which were those by Dalton, who published his researches in a collective form in 1871, under the title of *The Descriptive Ethnology of Bengal*. The first nucleus of an Ethnographical Museum we also owe to the Asiatic Society, the objects of which were subsequently transferred to the Indian Museum and now form part of its collections.

The lead given by the Asiatic Society h in other parts of the country, as a result of which the Ant Society of Bombay, which celebrated its fiftieth anniversary last year, was founded in 1886 under the presidency of Edward Tyrrell Leith.

Earlier Ethnological Works

The necessity of obtaining reliable information on the people of India in the interests of civil administration drew the attention of the Government of the time to the useful work done by the Asiatic Society, and it began to encourage its officers to collect data on the social rites and customs of the people in the areas under their administration. The first Government officer to undertake this work was Ibbetson (afterwards Sir Denzil) who wrote an account of the social and religious usages of the Punjab in the Census Report of 1881, and which was published as a separate volume in 1883 under the title *Punjab Ethnography.* In 1891, Risley (afterwards Sir Herbert), under the instructions of Sir Rivers Thomson, then Lieutenant-Governor of Bengal, published his *Tribes and Castes of Bengal* in four volumes, which contained not only a mass of information on the social and religious institutions of the numerous communities living in Bengal, Bihar and Orissa, but also anthropometric data of the more important groups. Risley was followed by Crooke (afterwards Sir William), who published a similar work on the *Tribes and Castes of the United Provinces*, then known as the North-Western Provinces and Oudh, in four volumes in 1896. The formation of an Ethnographic Survey, covering the whole of India had, however, to wait a few years longer till Lord Curzon's Viceroyalty, but in the meantime, Risley was made the Commissioner of the Census of India for 1901, and in the Ethnographic Appendix (subsequently published under the title *The People of India*) he collected the general results of his investigations and elaborated his views on the origins of the Indian races and cultures. In 1905, Risley was appointed the Director of the newly formed Ethnographic Survey of India, and the various provincial governments undertook the task of publishing glossaries of tribes and castes living within their jurisdictions, on the lines indicated by Risley. The first of these was published by Edgar Thurston and T. Rangachari on the *Castes and Tribes of Southern India* in seven volumes in 1909. In the same year the late L. K. Ananthakrishna Iyer brought out the first volume of his *Cochin Tribes and Castes* under the auspices of the Government of Cochin. The first volume of H. A. Rose's account of the *Tribes and Castes of the Punjab and the North-Western Frontier Provinces* was published two years later. The completion of these and other works of the series took several years more and falls within the period of our survey, but the conception, method and the general plan of the works, though supplemented somewhat in the case of one or two, were on the lines indicated by Risley, and come logically within the first or preliminary

period of anthropological investigations in India which may accordingly be called the *Risleyan Period of Indian Anthropology.*

Later Developments

Since then the most important development in the growth of anthropological research in India was the starting of a modern laboratory in the Indian Museum by Dr. Nelson Annandale. Dr. Annandale, who took his doctorate degree in Anthropology from the University of Edinburgh, was a student of Sir William Turner, and led an anthropological and zoological expedition to Perak and the Siamese Malay States in 1901-1902, the results of which were published in collaboration with H. C. Robinson in the well-known work entitled *Fasciculi Malayensis.* Dr. Annandale started the first laboratory for Physical Anthropology and laid the foundations of modern research in that science in India—a subject in which he took unabated interest till his death in 1924. Similarly the creation of the department of Anthropology in the Calcutta University by Sir Ashutosh Mukherjee in 1920 gave for the first time official recognition to the importance of teaching and research in the subject by including it in the curricula of an Indian University. The promotion of anthropological research in India also received an impetus from the publication of '*Man in India*' in 1921, by Rai Bahadur S. C. Roy of Ranchi. Finally as a step towards co-ordinating the activities of the different centres of India, the Indian Anthropological Institute was founded in 1936 with Dr. J. H. Hutton as its first President.

The author takes this opportunity to express his thanks for the help given him in the preparation of this review by Dr. Eileen Macfarlane, Collaborator in Asiatic Research of the University of Michigan, U.S.A., (Budge Budge), Mr. J. P. Mills, I.C.S., (Shillong), Rai Bahadur S. C. Roy, (Ranchi), Messrs. S. S. Sarkar and H. K. Bose, (Calcutta). To Mr. K. P. Chattopadhaya, Head of the Department of Anthropology of the Calcutta University, he is specially indebted for a great part of the materials bearing on the subject of Social Anthropology.

II. General Anthropology.

The period following Risley's saw, as already remarked, the beginnings of more systematic research in Indian Anthropology, though the completion of the glossaries of tribes and castes begun under Risley's directions still remained the main occupation for many years to come. The first of these works to be finished was L. K. Ananthakrishna Iyer's *Cochin Tribes and Castes*, the first volume of which was published in 1909. With the publication of the second volume in 1912, the late Dewan Bahadur completed his studies of the social and religious institutions of the people of Cochin—with the exception of the Syrian Christians, on whom a separate monograph was published in 1926. Iyer's work is undoubtedly a very useful supplement to Thurston and Rangachari's

treatise and contains a mass of interesting data on the people of Malabar, but taken as a whole it lacks the insight and thoroughness of Fawcett's earlier studies (1901) on the same people.

The next work to appear was the *Ethnographic Survey of Baluchistan* edited by Bray (afterwards Sir Denys) in 1913, in two volumes. This work was based on the materials collected by Diwan Jamiat Rai during the Census of 1911, on the tribal, social and religious organizations of the Balooch, Pathan and Jat tribes, and a detailed account of the customs and usages of the Hindus who have made Baluchistan their home for many generations and have been influenced by the local milieu.

The work, *Tribes and Castes of the Central Provinces*, by R. V. Russell and Hiralal was published in 1916. The first volume is introductory and contains long dissertations on 'Caste' and the various religious sects found in the Central Provinces. The remaining three volumes include, among others, fairly exhaustive and well-informed accounts on the Gond, Khond, Kharia, Baiga, Korku, Oraon, Savar and other aboriginal tribes. With the exception of Risley's *Tribes and Castes of Bengal*, Russell and Hiralal's work is about the most reliable and authoritative of the whole series.

The other works of the series to be completed are :—

(i) *The Glossary of the Tribes and Castes of the Punjab and N.W. Frontier Provinces* by H. A. Rose, the final volume of which appeared in 1919. In reality, much of the previous writings of Ibbetson (1883) and Maclagan (1892) have been incorporated in these volumes, but in the sections dealing with the Moslems, Rose has given valuable indications of the influence exerted by the local milieu on the customs and habits of the Moslem population of the Punjab.

(ii) *The Tribes and Castes of Bombay* by R. E. Enthoven was published in 1922, in three volumes. Besides the usual notes on the tribes and castes found in the Bombay Presidency, Enthoven collected a large amount of historical and quasi-historical information from diverse sources on the origin and migration of some of the more important groups, like the Konkonasths (Chitpavans) of Maharashtra, and the Nagar Brahmins of Gujrat, etc.

(iii) *The Mysore Tribes and Castes* by H. V. Nanjunadayya and L. K. Ananthakrishna Iyer. The survey of the Mysore castes and tribes was undertaken by the late H. V. Nanjunadayya as early as 1903, and in the course of the next 17 years he published accounts of 34 castes and tribes and collected materials for 50 more. After his death, Iyer was entrusted with the task of completing the work in 1924. On the basis of the published and unpublished accounts left by Nanjunadayya, and supplemented by fresh investigations on 28 new groups, Iyer published Vols. II–IV between 1928–31. The method and plan of Risley were in general followed, but in volume I, which came out a few months before his death in 1936, Iyer published two introductions by Dr. R. R.

Marett of Oxford, and the late Professor Sylvan Levi of Paris, and two chapters on the Racial History and Cultural Geography of Mysore by Prof. Frhr. von Eickstedt of Breslau, and Mr. J. Richards, I.C.S. (retired), respectively. The chapter on Racial History is the English version of Eickstedt's paper 'Die Rassengeschichte von India, etc.' published in 1933 (*Zeits. Morph. Anthr.*, **32**). Iyer's own contributions embrace such subjects as Caste, Marriage, Totemism, Magic, Dress, etc., which he discusses with special reference to the conditions prevailing in Mysore.

These glossaries of tribes and castes were written with a great deal of care, and a large amount of money and labour were spent in collecting information on the caste and tribal groups of different parts of India, but as they were prepared 'primarily as works of reference for the officers of the Government who may desire to know something of the customs of the people among whom their work lies' (*Tribes and Castes of the Central Provinces of India*, I, Preface) they were not specifically meant to serve the requirements of the anthropologists, though no doubt of some interest to them. As Crooke, the author of *The Tribes and Castes of the North-Western Provinces*, and one of the earliest collaborators of Risley, remarked, 'treatises on tribes and castes have been compiled in various provinces of India . . . under orders of the local governments, not so much in the interests of anthropological research, but as indispensable aids to the work of civil administration. And the wants of the Magistrate and Collector and those of the anthropologist are very different'. (*Man in India*, **1**, p. 2, 1921.)

The criticisms implied in the above remarks, however, are not applicable to the works produced under the auspices of the Assam Government. Having under its jurisdiction a large number of tribal groups, the Government of Assam rightly felt that close administration of primitive peoples must proceed *pari passu* with increasing knowledge of their customs and habits. As a result, several excellent monographs were published with the financial support of the Government, on the Khasis, the Meitheis, the Mikirs, the Garos, etc., by Col. Gordon, Col. Hodson, Sir Charles Lyall, Major Playfair and others—men who not only took part in the annexation and pacification of the Assam hills, but who having spent many years among them had acquired an intimate knowledge of the habits and customs of the people. These works, therefore, though primarily designed for administrators, have been of great value to students of primitive culture in providing accurate and detailed accounts of the social and religious institutions of these comparatively unknown tribes.

In the monograph on the *Lushei-Kuki Clans* published in 1912, Col. J. Shakespear discussed the ethnography of the Lusheis proper including laws, customs, religion and the closely allied Kuki clans including the Thados of Cachar, and the Lakhers who recently migrated from the Chin hills across the Burman borders. Col.

Shakespear's treatment, as is to be expected from one who spent so many years among the Lusheis from the time of the annexation of the Lushei hills, is accurate and reliable, though not exhaustive.

With the appointment of Dr. J. H. Hutton to the Naga Hills district in 1913, anthropological research in Assam received a new impetus. Sharing fully the views of his predecessors about the importance of Anthropology for administrative purposes, but bringing to bear at the same time the trained mind of an accomplished scholar, Dr. Hutton carried on his researches for many years among the Naga tribes, after first acquiring a knowledge of their languages. His two volumes published in 1921 on the *Angami* and *Sema Nagas* reveal his intimate knowledge of the Naga life and habits and make them model works for accuracy and details of description.

The tribes living in the unadministered areas east of the Naga Hills, and between the Assam frontiers and the Upper Chindwin district of Burma, were almost unknown, though their depredations were constant sources of trouble in the British ruled territories. In order to survey this unvisited area and collect materials about the habits and customs of the people living there, Hutton paid two visits in 1923 to the Konyak, Phom, Kongan and Sema villages in the unadministered areas in company with J. P. Mills, Captain Shakespear and C. R. Pawsey. Accounts of these tours were published as *Diaries of two tours in the unadministered area east of the Naga Hills* (*Mem. As. Soc. Bengal*, **11**, pp. 1–72, 1929).

In connection with his work in the Naga Hills, Hutton was in close touch throughout with Prof. Henry Balfour of the Pitt Rivers Museum, Oxford, and the late Prof. R. B. Dixon, of Harvard, both of whom paid short visits to the hills and contributed materially in adding to our knowledge of the Naga tribes. In collaboration with the former he began a collection of the arts and crafts for the Pitts Rivers Museum, which was continued by his colleague and friend Mr. J. P. Mills, also of the Indian Civil Service, till the collection at Oxford became almost without a rival as illustrating every phase of life in a specified area. Hutton inspired Mills with his enthusiasm for anthropological research, and in 1922 the latter added the *Lhota Nagas* to the series of monographs published by the Government of Assam. In the same series there was published in 1925, the *Ao Nagas* by Dr. W. C. Smith of the American Baptist Missionary Society. As a broadminded clergyman and a trained sociologist, Smith noted the harmful effects produced on the Naga life by civilization, a subject which has since been more thoroughly investigated by Hutton and Mills. Smith's monograph on the Ao Nagas was immediately followed by another volume on the same tribe by J. P. Mills, in which he dealt exhaustively with the life and institutions of the tribe. A third volume on the Ao Nagas was published by Mr. S. C. Majumdar, who spent some years as a Medical Officer in the Naga Hills. In 1932, N. E. Parry published his detailed study of the Lakhers, briefly described in Col.

Shakespear's earlier work. The last volume of the series to be published so far by the Government of Assam, is that on the *Rengma Nagas* by J. P. Mills (1937). In this excellent work, Mills studied both the Eastern and Western sections of the tribe. The latter is however strongly influenced by the Christian Mission, but the former being long separated and cut off from communications from the parent stock by the Sema and Angami villages which lie between, still provides splendid opportunities for studying a tribe which retains much of the primitive institutions of the head-hunting Nagas. With the publication of this volume, the entire block of the Naga tribes living in contiguous territories has been covered with the exception of the Konyak Nagas, among whom Dr. Christoph von Fürer-Haimendorf of the Vienna University has just spent a year making an intensive study of their institutions in close collaboration with J. P. Mills. A word is needed here on the debt which Science owes to the Government of Assam. It has consistently encouraged its officers to study Anthropology and has ungrudgingly borne the entire cost of publishing the volumes written by its officers. This has made it possible to investigate and record the customs of primitive tribes before deterioration has set in. A large group of tribes has thus been covered by monographs, and materials invaluable for comparative study assembled, to the lasting gratitude of students of primitive culture.

There are a few other works which were published on Assam tribes, but not under the auspices of the Government. Chief among these are :—

(i) *The Abors and Galongs* (*Mem. As. Soc. Bengal*, **5**, pp. 1–113, 1915), Part I by G. D. S. Dunbar, Part II by J. Coggin Brown and S. W. Kemp, and Part III by G. D. S. Dunbar (1917). This memoir was based on the materials collected by Dunbar after 4 years' stay in this region, on the customs and religious rites of the Upper Abors who live in the Kamla valleys and Western Dafla hills and their more westernly neighbours, the Galongs. Short notes are included on the Mishmis and the Daflas. These accounts, though not exhaustive, are accurate and are our only source of authentic information on the habits of these tribes. Part II contains anthropometric measurements of male and female Abors, and Part III contains the personal narrative of a visit of Dunbar up the Dihong valley to Pemakoichen, with interesting notes on the Membas, who inhabit this territory and are in reality the easternmost branch of the Tibetans.

(ii) *Notes on the Thadou Kukis* by William Shaw (*Journ. As. Soc. Bengal*, **25**, pp. 1–175, 1929). The author spent 7 years as a subdivisional officer in the N.-W. area of the Manipur State which is chiefly occupied by the Thadou Kukis. His accounts of the arts, crafts, social and religious customs of the tribe are fairly exhaustive and reliable, but being based on the *Shitlho* clan, refer primarily to

this important group, though no doubt holding good of the Thadou Kukis in general.

To the same class belong the works of S. C. Roy in the Chota Nagpur plateau. Coming to practise as a lawyer, 40 years ago in Ranchi, he was moved by the oppressions and hardships of the Munda tribes at the hands of aliens, who were placed over the heads of the Munda village communities through the ignorance and apathy of the Government authorities. The administrative and judicial officers having been ignorant and unmindful of the agrarian history of the Munda country did not take any effective measures to see that proper justice was done to them in respect of their agrarian grievances and difficulties. To remedy this state of affairs, Roy learnt the Munda language and prepared a detailed account of their tribal organization, laws and customs, which was published in 1912 under the title of *The Mundas and their Country.* Roy's book removed a long-felt desideratum by giving a detailed account of the Munda institutions and was acknowledged by the High Court of Judicature as authoritative; and the Government of Bihar under the initiative of Sir Edward Gait, then Lieutenant-Governor of Bihar, encouraged him in his work with financial assistance. The next tribe studied by Roy was their neighbour, the Oraon. In the two volumes published on this tribe, namely *The Oraons of Chota Nagpur* in 1916, and *The Oraon Religion and Customs* in 1928, he showed that like the Mundas, they too have a patrilineal social system, the same type of village Panchayat, and a wider organization composed of a number of *Parhas* or federations associated together for certain common purposes. Unlike the Mundas, however, the Oraons have no regular ancestor-cult, although the spirits and supernatural powers that they believe in and strive to appease, are generally of the same pattern, and in a few instances common with those of the Mundas. One noticeable distinction is that, whereas, all the calamities of life are attributed by the Mundas to the spirits, the Oraon's first impulse is to attribute them to witchcraft or the Evil Eye. Roy was also the first man to draw attention to the existence of a well-organized dormitory system for bachelors among the Oraons—a system which he subsequently discovered among Kharias and other tribes of the 'Central Belt'.

Roy's investigations were not, however, confined to these two tribes but embraced the other Munda-speaking peoples of this region. He published his account of the *Birhors* in 1925, followed ten years later by his monograph on the *Hill Bhuinyas of Orissa*, who although belonging to the same Munda stock have now adopted Uriya as their language. These people still practise the *Jhum* cultivation, but show the effect of acculturation with Hindu culture as a result of contact with their more civilized neighbours—the Ooriyas. The last work to be published by Roy is *The Kharias* (2 volumes) this year. This monograph, prepared in collaboration with his son,

R. C. Roy, deals with all the three sections of the Kharia tribe, namely the Hill, the Dudh and the Dhelki, extending from Mayurbhanj to the Jashpur States of the Central Provinces, and present different strata of primitive culture. Roy gives an exhaustive account of the Kharia institutions and corrects many inaccuracies in the accounts published by the earlier writers.

Like his colleagues in Assam, Roy has covered a large block of tribes living in contiguous territories, with firsthand intensive researches on their social and religious institutions, and has laid anthropologists under a deep debt of gratitude by providing reliable and detailed information for comparative studies, on the Mon-khmer speaking peoples living in the highlands of the Santal Parganas and the adjacent tracts.

In no other part of the country systematic investigations of such a nature has been carried out, but valuable and reliable accounts of several castes and tribes have appeared. To this category belong the monographs published on several of the Burman tribes. They are :—

(i) *The Shans* by W. W. Cochrane published in 1915, in which the author has discussed the origin and early history of the Shans of Burma, Yunnan and lower Cambodia. A general account of their language, affinities and religion has also been given.

(ii) *The Talaings*, published in 1917 by R. Halliday, who after studying them both at home and across the frontiers in Siam has striven to give an account of the genuine rites and customs of the Talaings, as distinguished from those which usually pass off under that name.

(iii) *The Karen People of Burma* by the Reverend H. I. Marshall, published by the Ohio University in 1922, is undoubtedly the best of the series. The author was in charge of the American Baptist Mission among the Karens for many years, and had the advantage of receiving a training in Anthropology under Prof. Siebert of the Ohio State University, and Drs. Laufer and Fay Cooper-Cole of the Field Museum of Natural History of Chicago. He has given a detailed account of the domestic, social and religious life of the Sgaw branch of the Karen people. Besides these, the arts and crafts of the Karens have been fully described, and there is also an excellent general description of their physical traits, with well-selected photos.

(iv) In *The Home of an Eastern Clan* (1924), the authoress, Mrs. Leslie Milne, who spent many years among the Palaings of the Shan States, has described in some detail social and religious institutions of this interesting tribe from personal knowledge. Though not exhaustive, it gives a good reliable account.

Of the other monographs published, one of the most important is the *Life History of a Brahui* written by Sir Denys Bray in 1913. It gives an account of the Brahui life from birth to death, with all the rites and ceremonies associated with its different cycles, told

by Mirza Sher Muhammad, himself a Brahui of the Jhalawan tribe and deeply versed in the customs and institutions of his race.

In *The Andaman Islanders* (1922), A. R. Brown, who has recently been appointed to the Chair of Anthropology in the University of Oxford, published the results of his field researches in the Andaman Islands during 1906–08, as Anthony Wilkin Student of the University of Cambridge. Brown's investigations refer primarily to the North Andamans, and his book is one of the standard works on the social and religious institutions of the Andamanese. His researches, as embodied in this book, have no doubt considerably added to our knowledge about the Andamanese, specially the chapter on Technical Culture, but his interpretation of the Andamanese customs and beliefs must be regarded as somewhat speculative.

The most authoritative account of the Andamanese, however, is given in E. H. Man's *Aboriginal Inhabitants of the Andaman Islands* (1932), which the Royal Anthropological Institute of Great Britain and Ireland has published in a revised form. During his thirty-two years' stay in the Andaman Islands as Assistant Superintendent (1869–1901), Man acquired a most intimate knowledge of the language and customs of the Islands. This, as also his work on the *Nicobar Islands and Their People*, published in the same year by the Royal Anthropological Institute of Great Britain and Ireland, are the posthumous collections of his papers edited by his sister, who was long associated with him in his work. These are the best sources of our information on the two aboriginal tribes living in the Islands of the Bay of Bengal.

Finally, one may mention, *The Vaishnavas of Gujrat* by N. A. Toothi (1935), in which the author has described the social organization, and rituals and observances of the different Vaishnava sects and subsects found in Gujrat as a result of personal investigations extending over many years.

III. Prehistoric Archæology.

Stone artifacts, both crude and polished, have been found in great abundance in India along river beds and hill terraces and accounts of them have been published by several earlier workers such as H. F. Blanford, V. Ball, N. C. Logan, etc. A systematic description of these objects was given by R. Bruce Foote in his work entitled *The Indian Prehistoric and Protohistoric Antiquities* (1916). Similarly in his *Catalogue of the Prehistoric Antiquities, etc.* published in the following year, J. Coggin Brown gave an account of the stone implements in the collections of the Indian Museum. In 1923, Panchanan Mitra, in his work on *Prehistoric India*, put forward a classification of the Stone Age cultures of India on the analogy of European culture-sequences on typological grounds. A more serious and critical attempt was that of H. C. Das Gupta

(*Journ. Dept. Sc., Cal. Univ.*, **6**, 1923), who sought to determine the chronology of the Indian finds from associated fossil animal remains found in some places, such as the Siwalik beds. It was not, however, till the recent Yale-Cambridge India Expedition led by Hellmutt de Terra, that definite stratigraphic evidence for the Age-sequences of the Indian Stone-Age cultures was discovered. The de Terra Expedition made a systematic survey of the country lying between the Indus and Jhelum, from the Kashmir Valley to Pir Panjal and from Poonch to the Salt Range, and found a large number of prehistoric sites from Early Palæolithic to the Neolithic ages. The most characteristic of these cultures existed in the Soan Valley (from which he gave this culture its name), ranging from Early to Late Middle Palæolithic times. De Terra was able to correlate them with the glacial cycle of Kashmir and thus provide for the first time a tentative chronology of the Stone Age Culture sequences of India. The 'Soan' culture was essentially a flake culture reminiscent of the Mousterian industry of Western Europe and was without doubt the source from which the Palæolithic cultures of the Narbadda Valley, Western Ghats and S. India were derived (*Misc. Amer. Philos. Soc.*, **1**, No. 2, 1936 ; *Nature*, April 25, 1936).

His further work on the Megalithic sites of Kashmir showed that in India, also, this culture had a Neolithic basis, characterized by polished stone implements, and a 'band-ceramic' recalling the Neolithic pottery of Central Europe. This 'black burnished' ware is identical with that found in Mohenjo-daro and in Baluchistan and Persia during the Chalcolithic times, and suggests that the 'Indus' Civilization was probably superimposed on an older Megalithic Culture already existing in the Indus Valley, the discovery of which by R. D. Banerji in 1922 marked, not only an era in Indian history, but is comparable to the effect produced by Schliemann's discoveries in Greece and Asia Minor.

Attention was drawn to the significance of these discoveries by Sir John Marshall in 1924 (*Illustrated London News*, September 20, 1924), but the first official account of the 'Indus' Civilization was published in 1931 in his *Mohenjo-daro and the Indus Civilization* (3 vols.). The results of excavations at Mohenjo-daro during 1922–27, which are described in this work, revolutionized all existing ideas, not only on the origins of the Indian but also on that of human civilization in general. There are many elements in the Hindu Religion such as the cults of Siva, the Mother Goddess, and much of Zoolatry, which are not traceable to the Vedic Aryans,—found their explanations at last in the faiths that existed in the Indus Valley and throughout the Near East during the Chalcolithic times.

The extension of the 'Indus' Civilization further westwards in Baluchistan was shown by the excavations at Nal by H. Hargreaves (*Mem. Arch. Surv. of Ind.*, No. 35, 1929), and in Wazaristan, Northern Baluchistan and the whole of Gedrosia by

the explorations of Sir Aurel Stein in 1929 and 1931 (*Mem. Arch. Surv. of Ind.*, No. 39, 1929; *Mem. Arch. Surv. of Ind.*, No. 43, 1931). N. G. Majumdar (*Mem. Arch. Surv. of Ind.*, No. 48, 1934) in his careful survey of Lower Sind has explored innumerable sites belonging to this Civilization along both banks of the Indus almost as far south as the Arabian Sea, one of which, viz., Chanhudaro has recently been excavated by Dr. E. Mackay on behalf of the American School of Indic and Iranian Studies and the Museum of Fine Arts, Boston (*Bull. Mus. Fine Arts, Boston*, **34**, pp. 83–92, 1936). Seals bearing the Indus script have been discovered at Kish and other Sumerian sites and H. Frankfurt (*Ann. Bibl. Ind. Arch.*, **7**, pp. 1–12, 1934) has recently drawn attention to the close similarity of some of the Mohenjo-daro finds with those of Tell Asmar, suggesting trade communications, if not a common origin for the ancient civilizations of the Indus and the Tigris-Euphrates valleys.

Direct reference to the 'Indus' people in early Sanskrit literature is not clear, though Ramaprasad Chanda (*Mem. Arch. Surv. of Ind.*, No. 31, 1926; *Mem. Arch. Surv. Ind.*, No. 41, 1929) has suggested that passages in certain Vedic texts clearly allude to their beliefs and habits. It cannot, however, be said that the gulf separating our knowledge of the Vedic from the 'Indus' Civilizations has, in the absence of a key being yet discovered for deciphering the ancient script of the Indus Valley people, at all been bridged.

Mention has been made of de Terra's discovery of a Megalithic Culture in N.-W. India dating back to the Neolithic times. Throughout the highlands of Central India there are innumerable remains of a Megalithic character, but no systematic excavation of any of these sites has as yet taken place. The explorations carried on by S. C. Roy and E. A. Murray have, however, given us some idea as to their nature and contents. The remains surveyed by Roy (*Journ. Bihar and Orissa Res. Soc.*, **1**, pp. 229–233; **2**, pp. 485–487; **6**, pp. 393–343) consist of ancient brick structures, silted up tanks and huge slabs and columns of sepulchral stones attributed by the Mundas to 'Asuras', who were supposed to have occupied the land before them. Over 18 of them were examined by him from Belwadag in the vicinity of Khunti, the subdivisional headquarters of the Mundas, to Sangrigaon and Indpirl, at the southern end of the Ranchi district. No human remains were found, but polished stone implements of various kinds, cornelian beads, wheel made pottery with geometric designs, and large quantities of copper and bronze objects were unearthed. Cinerary urns, phallic symbols, iron objects, iron slags and kilns for smelting them were also discovered. E. A. Murray's excavations of the Ruangarh ruins (*Census of India*, **1**, part 3, 1935) on the spur of a hill in the copper-belt of the Dalbhum district (near Tatanagar) recovered objects similar to those found by Roy, namely, polished stone implements, potsherds, cornelian beads, copper and gold ornaments and iron slags besides two human skulls.

In Southern India and the Deccan, where the Megalithic remains occur in largest numbers, excavations took place very early, and in the accounts published by Meadows Taylor (*Trans. Roy. Irish Acad.*, **24**, 1873) and J. W. Breeks (*Primitive Tribes of the Nilgiris*, London, 1873) in the latter part of the nineteenth century, we possess materials of the highest value. Since then a considerable amount of work has been done on these remains in several parts of S. India, and in the State of Hyderabad particularly. In 1912, A. H. Longhurst (*Ann. Rep. Arch. Sur. Ind.*, 1911-12) published an account of a rockcut tomb near Calicut, and two years later (*Ann. Rep. Arch. Sur. Ind.*, 1913-14) of a number of cairns and stone cists at the foot of the Nilgiri hills in the Coimbatore district. But the most important work was that of E. H. Hunt (*Journ. Roy. Anthr. Inst.*, **54**, 1924). Stationed for many years as a British Medical Officer in Secunderabad he was early interested in these ruins and carried out a systematic excavation of the stone cists, etc. at Raigir and other parts of the Hyderabad State. He was followed by L. Munn (*Ann. Rep. Arch. Sur. Hyd. State*, 1915-16), G. E. C. Wakefield (*Ann. Rep. Arch. Sur. Hyd. State*, 1917-18) and G. Yazdani (*Ann. Rep. Arch. Sur. Hyd. State*, 1915-16), all of whom excavated a large number of cromlechs, cairns and stone circles in Raigir, Janampit and Maula Ali in the Hyderabad State. Further south in the Tamil country, 18 miles from Vellore, near the site of the ancient city of Kanchi, F. J. Richards (*Journ. Roy. Anthr. Inst.*, **54**, 1924) opened three stone circles at Odygathur and Numa Laffite (*Rapport D'ensemble sur les Fouilles Executees dans le Sud de L'Inde.*, Paris, 1932) of the French Colonial Health Service has recently published an account of his excavations of the stone circles at Tiruvicar, Permibe and Montapalam in the Coromandel Coast, about 20 kilometres from Pondichery.

These excavations show the general uniformity of the ruins as judged from the same type of red and black wares, cinerary jars, terra-cotta sarcophagi, cornelian beads and bronze and iron objects found in abundance. The high percentage of tin, ranging from 19 to 21 in bronze objects of the Nilgiri hills and Hyderabad (Deccan), is similar to that found in the ' central belt ', where the percentage of tin is sometimes as high as 23·8. In the ancient Indus Valley on the other hand, in none of the specimens examined it exceeded 12·13. This, and the similarity of objects, appear to link the cultures of Central and Southern India directly, showing that in all probability the Megalithic culture migrated southwards after a knowledge of working out the metals was acquired, and bronze objects continued to be imported in the south from Central India.

Whether the Megalithic culture found in Assam and the North-Eastern Frontiers can also be regarded as originating from the same source is not as yet quite clear, though the researches of J. H. Hutton would seem to suggest that it was due to a later movement of Mon-khmer people from South-Western China. These

stone monuments of Assam were widely known and described from the earliest times, but J. H. Hutton was responsible for bringing out their true significance for the first time. In a paper published on the monoliths of Dimapur (*Journ. Roy. Anthr. Inst.*, 52, 1922) followed by two others on the Jamuguri monuments of Dayang Valley (*Ibid.*, 1922 and *Journ. As. Soc. Beng.*, **20**, 1921). Hutton showed that they were connected with fertility rites. He carried his investigations on these monuments further into the Naga hills (*Journ. Roy. Anthr. Inst.*, **56**, 1926) and found that they were also connected with the same cult. His further studies convinced him that the cult of the stone in Assam was associated with ancestor worship, and not directly connected with the Megalithic culture of Central India, but was due to a later movement from South-Western China, and closely linked up with the same culture found in Oceania (*Man in India*, **8**, 1928 ; *Antiquity*, Sep. 1929).

There are, therefore, two sources from which the Megalithic cultures of India were possibly derived, but there does not appear to be much reason to trace either of them directly to Egyptian sources as seemed probable—to many at one time (P. Mitra, *op. cit.*, 1923 ; G. S. Ghuriye, *Man in India*, **6**, 1926), though further researches are undoubtedly necessary to bridge the gap that now exists between our knowledge of the Neolithic Stone Cult of N.-W. India and the later metal using Megalithic Culture of Central and Southern India.

IV. Physical Anthropology.

Since Risley's work, investigations in Physical Anthropology were mainly directed towards : (1) studies of the skeletal remains of India's past population recovered during excavations of prehistoric sites in recent years, and (2) Somatic characters of selected groups of living population.

(*a*) *Craniometry and Osteometry.*

The earliest account of note on prehistoric man in India was that published by Sir Arthur Keith in 1917 (*Jour. Anthr. Soc., Bombay*, **11**, No. 6) on the Bayana and Sialkot skulls. The former was found at Bayana a few miles from Agra by Wolff in 1910, at 35 ft. below the level of the river bed, during the construction of a railway bridge, and the latter by Hingston in 1912 near Sialkot at a depth of 6 ft. below the level of the land. Though the definite ages of the skulls are uncertain, the former appears to be of considerable antiquity, as judged both by the degree of mineralization it has undergone and the great depth of the alluvial bed in which it was found. The latter would appear to be more recent, and in consistency, not unlike the bones of the Chalcolithic times in the Indus Valley. In the Sialkot skull the facial part is entirely missing,

but in the Bayana, enough of nasal bone remains to show that it was narrow and high pitched. The cranial shape is long and both disclose undoubted 'Mediterranean' affinities.

The other accounts on prehistoric bones in India are those published by R. B. Seymour Sewell and B. S. Guha on (i) The Human Remains excavated at Nal by H. Hargreaves (*Mem. Arch. Surv. of India*, No. 35, 1929); (ii) The Human Remains recovered by Sir Aurel Stein in Makran (*Mem. Arch. Surv. of India*, No. 43, 1931); (iii) The Human Remains excavated at Mohenjo-daro during 1923–27 (*Mohenjo-daro and the Indian Civilization*, 2, 1931); and by B. S. Guha and P. C. Basu; (iv) on The Human Remains excavated at Mohenjo-daro by E. Mackay during 1928-29 (*Further Excavations at Mohenjo-daro*, 1937).

In these Memoirs Sewell and Guha, and later Guha and Basu showed that during the Chalcolithic times in the Indus Valley and Baluchistan, the chief racial types were similar to those existing at Kish and Al'Ubaid in pre-Sargonic Sumeria, and consisted of the 'Mediterranean' strain, a largebrained longheaded type of possible Proto-Nordic affinities and plano-occipital broadheaded race characteristic of Asia Minor at the present times.

In the Nal Collection of bones which consists of the remains of 13 individuals, ranging from an young adult to an infant of one year, Sewell and Guha observed some special features of considerable morphological significance, namely, the change produced in the shape of the acetabular cavity, the gradual migration inwards of the pilaster and fossa hypotrochanterica, the anterior prolongation of the articular surface between the astragalus and the os calcis, and the decrease in the Cnemial index from childhood to adult life, caused by the influence of altered strains and stresses on the bones and articulations, due to the adoption of the squatting posture. Besides these, G. Elliot Smith (*Evolution of Man*, 1924) published a short note on two skulls from Aditanallur, excavated by A. Rea in 1901 and sent to him for examination. In 1930, a more detailed account of the same was published by S. Zuckerman (*Bull. Mad. Govt. Mus.*, N.S. **2**, 1930) under the directions of Prof. Elliot Smith, in which the Australoid character of the one was confirmed, but the other was held to be more closely allied to the 'Armenoid' rather than to the usual 'Mediterranean' type.

On the skeletal remains of the modern Indian population, L. R. Sullivan (*Anthr. Pap. Amer. Mus. Nat. Hist.*, **23**, 1921) published a comparative study of some Andamanese and other Negrito skulls. In the same year was published M. L. Tildesley's first study of the Burmese skulls (*Biometrica*, **13**, 1920-21) in which she made the application of Pearson's C.R.L. method for the first time. The crania studied by her were procured by Col. Chester, from a cemetery near Moulmein. The Burmese skulls investigated by P. C. Basu (*Trans. Bose Res. Inst.*, Cal., **7**, 1933), belonging to the collections of the Indian Museum, came from Pegu, from a known

cemetery near Prome, and therefore refer to a more north-westernly region.

Of the unadministered part of Burma west of the Hukong valley and inhabited by the wild Naga tribes, the Triangular Expedition led by T. P. Dewar brought a large number of skeletal relics of the victims of human sacrifice, which were studied by B. S. Guha and P. C. Basu (*Anthr. Bull. Z.S.I.*, No. 1, 1931). These revealed the presence of a non-Mongoloid type with marked development of the supra-orbital regions accompanied by a depression of the nasal root, and seemed to confirm Hutton's previous observation of Negroid strains in the Naga country (*Man in India*, 7, 1927).

The concluding part of Sir William Turner's memorable researches on Craniometry of the Indian people (*Trans. Roy. Soc. Edin.*, **49**, 1914) contained also accounts of several skulls belonging to the Chinboks, Taungthas, Jaws of the Chin hills and the Southern Shan tribes. In this memoir, Sir William also published his investigations on the crania of the Bhils of Central India. Two more papers appeared, dealing with the skeletal remains of the aboriginal tribes of this part of the country, namely, P. C. Basu's study of the Munda crania (*Trans. Bose Res. Inst.*, Cal., **10**, 1935). The crania investigated by Basu were obtained by W. H. P. Driver and Col. Dalton for the Indian Museum, from the neighbourhood of the Ranchi district, and disclosed the strikingly Australoid character of some of the Munda crania.

The last papers to be mentioned though not the least in importance are the two dealing with the Dravidian-speaking peoples of Southern India. In the former published by G. Harrower (*Trans. Roy. Soc. Edin.*, **44**, 1925-26), 35 authentic crania, belonging to the Tamil coolies who died in the King Edward VII Medical College Hospital at Singapore, were studied. Harrower made a careful morphological examination of the crania, and statistically analysed his measurements according to Pearson's method of the C.R.L. Similarly R. K. Rau published an account of Telegu crania (*Census of India*, **1**, pt. 3, 1931) which belonged to Cadavars from King George's Hospital in Vizagapatam, records of whose age, sex and nationality were preserved. C. Mascerenhas' investigations on 20 Goanese skulls also deserve mention (*Argv. da Esc. Med. Cir. de Nova Goa*, Serie A, pp. 1348–61, 1931).

These papers give us our only sources of information on the cranial characters of the South Indian people, based mostly on skulls about whose authenticity there is no room for doubt—a desideratum not fulfilled in collections made previously from Southern India.

(*b*) *Anthropometry*.

The survey of Sir Aurel Stein in the North-Western Frontiers of India is the first important work undertaken in Anthropometry

during the period of this review. Our knowledge of the races living in these regions was hitherto due solely to the labours of Baron Mezö-Kövesd Ujfalvy, who visited them in 1881-82 under the auspices of the Sociètè d'Anthropologie de Paris. In the course of his three Archæological Expeditions to Russian and Chinese Turkestans during the years 1900–1928, Sir Aurel found time to measure over one thousand individuals belonging in the main to tribes living outside India's frontiers, but including also seven within her boundaries, namely, the Baluch of Baluchistan, the Pathans of Swat and Torwal, the Red Kaffirs, the Khos of Chitral and Mastuj and the Hunzas of Gilghit. Stein's measurements comprising 10 characters, and supplemented by careful observations on the skin, eye and hair colours, etc. constitute our chief and only materials on many of these tribes. Most of his data were analysed by T. A. Joyce with the half of the equation known as the 'Differential Index' suggested by H. E. Soper and published in 1912 and 1916 (*Journ. Roy. Anthr. Inst.*, **42**, 1912; **46**, 1916). His data on the Baluch, the Pathan of Swat, the Torwali and the Hunza have recently been similarly treated by G. M. Morant who used Pearson's C.R.L. for his comparisons (*Journ. Roy. Anthr. Inst.*, **66**, 1936).

After Stein, measurements were taken by R. B. Dixon on the Burushaski people of Hunza-Nagar during a short visit to that region in 1912 (*Racial History of Man*, 1923), and by G. Dainelli, during the De Filipi Expedition to the North-Western Himalayas and Karakoram regions in 1913-14. Dainelli measured 530 men including the Kashmiri, the Ladakhi of the Upper Indus and Nubra valleys, the Dardic group consisting of the Machnopa and Bropka, the Balti and the Purigi who have now adopted Tibetan as their language. These materials were carefully analysed by R. Biasutti in two papers published in 1926 and 1930 (*Spedizione Italiana De Filipi*, Serie II, **9**, 1913-14; **2**, 1930) in which for the first time the author was able to isolate a short statured dolichocephalic mesorrhinic race which he considered to be an ancient pre-Aryan layer that has survived in these parts.

In 1922, Ramaprasad Chanda published measurements of a small sample of Kashmiri Brahmins (*Journ. Dept. Lett. Cal. Univ.*, **8**), and in the summer of 1929 an expedition was sent by the Zoological Survey of India to collaborate with G. Morgensteirne who visited the North-Western Frontiers of India on a linguistic mission on behalf of the Norwegian Institute for Comparative Research in Human Culture. Measurements on 700 men were taken by the present writer during this expedition, on the Kaffir tribes of Rambur and Bamboret, the Khos of lower and upper Chitral, the Pathans of Bijaur, etc., besides a large number of Tadjiks and Uzbegs from Badakshan and Khasgar, who came to Chitral during that time (*Census of India*, **1**, pt. 3, 1935).

Of the Punjab plains immediately south of these mountain regions, Frhr. von Eickstedt has published an account of the physical

character of 144 soldiers captured by Germany during the War, of which 76 were Sikhs from the Eastern and 68 Mussulmans from the Western Punjab. From an analysis of these measurements, Eickstedt reached the conclusion that the population was racially homogeneous, though a robust, coarse, and a more refined subtype can be distinguished (*Zeits. f. Ethn.*, **52-53**, 1921; *Man in India*, **3**, 1923). Besides these, Eickstedt's subjects included also 13 soldiers from Gharwal and 27 Gurungs belonging to Western Nepal (*Mitt. Anthr. Ges. Wien.*, **56**, 1926; *Man in India*, **6**, 1926).

Further south in the lower Indus Valley the only metric data available are the measurements taken by R. B. Seymour Sewell and C. R. Roy on 100 Sindhi and 100 Brahui coolies of Mohenjo-daro during the excavation season of 1927-28 (*Census of India*, **1**, pt. III, 1935).

In Western India, Dr. I. Karve (*Zeits. Morph. Anthr.*, **29**, 1930) carried out a careful survey of the eye colours of over three thousand Chitpavan Brahmins, both men and women, between the ages of 1–54 years. But the most systematic and comprehensive investigations were those undertaken by A. C. G. da Silva Correia and his pupils in the Southern Marhatta country, and particularly in Portuguese India. Da Silva Correia published his first work (*Les Ranes de Satary*, Nova Goa, 1928) on the descendants of the Rajput nobles who dominated parts of Malabar in the 15th and 16th centuries and afterwards made Satara their home. His next study was on the mixed Indo-Portuguese population of Nova Goa (*Argv. da Esc. Med. Cir. de Nova Goa*, Serie A, **2**, 1928). In the following year, his pupil V. Camotin published his researches on the somatic characters of the Saraswat Brahmins (*Os Bramanes Sarasvats de Goa*, 1929), and held that on anthropometric grounds, the Saraswat Brahmins of Nova Goa appeared to be related to the Brahmins of Gourdeshā or Bengal. Da Silva Correia's further researches comprised: (*a*) a complete anthropometrical and morphological study of the children between the ages of 10–21 of the Portuguese parents residing in Nova Goa (*Argv. da Esc. Med. Cir. de Nova Goa*, Serie A, **7**, 1931); (*b*) an exhaustive work on the Marhatta population of Portuguese India (*Les Maharattes de l'Inde Portugaise, Nova Goa*, 1934), in which he published the results of his studies on 162 adults including an analysis of the blood-group tests on 400 men; and (*c*) a comprehensive study of the Goanese Mussulmans (*Les Musulmans de l'Inde Portugaise*, 1937), which included his investigations on the somatic characters of 100 male subjects, their blood-group tests, and other morphological and ethnological characteristics.

F. X. R. da Costa Pegado (*Argv. da Esc. Med. Cir. de Nova Goa*, Serie A, 7, 1931) is responsible for a very important investigation on the soft parts of the inhabitants of Nova Goa who died in the hospital attached to the Medical School. He observed certain

important differences between the upper and lower castes, such as the absence of muscle palmaris longus in the latter.

The investigations of da Silva Correia and his pupils and colleagues furnish us with detailed systematic studies on the physical characters of the different sections of the population of Portuguese India.

Other studies on Peninsular India worth noting are: (*a*) a short account of the head-form of the Moslems of Pulicat based on the measurements taken on 100 subjects by S. T. Moses (*Man in India*, **3**, 1923); (*b*) an excellent account of the Somatic characters of the Parawar, Shanan and Parayan castes of the Tinnevelly district published by J. Hornell (*Mem. As. Soc. Bengal*, 7, 1920). Hornell's measurements showed the presence of a strong brachycephalic element among the Tamil coastal population which he considered to be due to a Polynesian immigration bringing with it the outrigger canoe and cocoanut to India; (*c*) researches on the Kadar and the Malayan tribes in the interior of the Annamallais and the adjoining Perambiculum hills by the author during 1928-29 (*Nature*, **121**, 1928; and **123**, 1929) which disclosed for the first time the presence of a Negrito racial strain among these tribes; and (*d*) L. A. Krishna Iyer's studies on the physical characters of the primitive tribes of Travancore (*Pr. Ind. Ac. Sc.*, **4**, 1936) in which measurements on 252 individuals comprising 10 groups were published.

For the north-eastern part of the country J. Coggin Brown and S. W. Kemp (*op. cit.*, **5**, 1915) published measurements on the male and female Abors living in the Kamla Valley and the Western Dafla hills. The measurements on the Angami and Sema Nagas taken by R. B. Dixon were published by Hutton in the Appendix of his monograph on the former tribe (*The Angami Nagas*, 1921). Dixon also published an account of the racial affinities of the Khasis (*Man in India*, **2**, 1922), on the basis of the measurements taken by him in Shillong. Attention was drawn to the presence of frizzly hair among the Angami Nagas by J. H. Hutton (*Man in India*, **7**, 1927), who considered it to be due to an underlying Negrito substratum in the population of this part of the country.

In Assam proper no investigations have taken place after L. A. Waddel's work in 1901, but in Bengal, R. P. Chanda published his measurements on 216 men belonging to the Brahmin, Kayastha, Vaidya, Tili and Kaibarta castes (*The Indo-Aryan Race*, 1916). This work was the first to expose the weaknesses in Risley's account of the origin of the Indian races, and marked a departure in the anthropological literature of the time, by suggesting that the brachycephalic people of India as a whole were parts of an earlier race movement from Central Asia. They were later on forced out from the 'Madhyadesa' by the Vedic Aryans, and formed a sort of an outer ring round them—a view subsequently adopted by V. Giuffrida Ruggeri (*The First Outlines of a Systematic Anthropology of Asia*, Trans. by H. Chakladar, 1921).

The elaborate measurements taken by N. Annandale since the installation of his laboratory in the Indian Museum, consisted among others of a series of Anglo-Indian population of Calcutta, numbering over 200 subjects. P. C. Mahalanobis was entrusted with the task of giving the biometrical analysis of these materials, and he has so far published his analyses on stature (*Rec. Ind. Mus.*, 33, Part I, 1922) and Head Length (*op. cit.*, Part II, 1931). Mahalanobis has also analysed Risley's anthropometric data by means of certain alternative formulæ devised by him for statistically determining divergences between different racial groups (*Journ. As. Soc. Bengal*, **22**, 1927). The theoretical foundations of these tests (called D^2) were discussed by him [*Journ. As. Soc. Bengal*, **26**, 1930; *Proc. Nat. Inst. Sc. Ind.*, 2(1), 1936]; by R. C. Bose [*Sankhya* 2(2), 1935] and by S. N. Bose [*Sankhya* 2(4), 1936; 3(2), 1937]. Mahalanobis' D^2 tests were applied by him in analysing Shirokogoroff's materials on Northern and Eastern China (*Man in India*, **8**, 1928).

Other investigations in Bengal include (i) a study of the Varendra Brahmins by T. C. Rai Chowdhuri (*Man in India*, **13**, 1933) who measured 179 male adults of the Nadia district, (ii) A. K. Mitra's measurements of 875 individuals belonging to the Vaidya, Subarnabanika, Mahisya and Namasudra castes of Western Bengal (*Census of India*, **1**, pt. III, 1935), and (iii) H. C. Chakladar's work on the Muchis (*Proc. Ind. Sc. Cong.*, 1936). In addition U. Guha has measured 250 Bengali women of the Brahmin, Vaidya and the Kayastha castes (*Census of India*, **1**, pt. III, 1935) and B. N. Datta has published a note on the incidence of the Darwinian tubercle in 66 male subjects belonging to Bengal (*Man in India*, **14**, 1935).

In Bihar, besides the measurements published by R. P. Chanda on 144 subjects of the Brahmin, Babhan and Chattri castes (*op. cit.*, 1916), B. K. Chatterjee is responsible for a very careful study of the Maithil and Kanaujiya Brahmins of the districts of Darbhanga and Bhagalpur (*Anthr. Bull. of Z.S.I.*, No. 2, 1934). Chatterjee's analysis showed that the two groups are really samples of the same racial stock, but differ from the predominantly brachycephalic Brahmins of Bengal.

The rest of the published works concern chiefly the aboriginal population of Central India, the earliest of which was by D. Majumdar on the Hos of Kalhan (*Man in India*, **5**, 1925). P. C. Basu began a systematic survey of the tribes of the Santal Parganas and published two important memoirs on the Somatic characters of the Mundas and Oraons (*Trans. Bose Res. Inst.*, **9**, **10**, 1932–34). Basu also published an account of the anthropometry of the Bhuinyas of Mayurbhanj (*Journ. As. Soc. Bengal*, N.S. **24**, 1929). Lastly attention was drawn by S. Sarkar (*Nature*, **137**, 1936) to the presence of spirally curved hair among the aborigines of the Rajmahal hills, of whose physical characters a very detailed account has

recently been published by him (*Trans. Bose Res. Inst.*, **12**, 1937); and a chapter on the physical characters of the Kharias was included in the recently published work on the Kharias by S. C. and R. C. Roy (*op. cit.*, 1937) in which D^2 test of Mahalanobis was used in analysing the data.

A reference is necessary to the very important paper of R. B. Seymour Sewell on the origin of man and the population of India in the past and future (*Pres. Add. Sixteenth Ind. Sc. Congr.*, 1929) in which he sought to explain the cause of brachycephaly as due to living in high altitude in the formative period of man's life-history.

The morphology of hand and finger marks have of late received increased attention in America and Europe as a fresh line of investigation in physical anthropology, and P. C. Biswas has started similar investigations on Indians (*Zeits. Morphol. Anthr.*, **35**, 1936).

Mention should also be made of the survey by Lidio Cipriani among the tribes living in Travancore, Cochin, Coorg and the Nilgiri hills during 1934-35, in which measurements were taken on 2,323 individuals, belonging to 36 groups. A full account of his investigations has not as yet appeared, but in a preliminary communication on his work in Coorg (*Arch. per l'Anthro e la Etn.*, **65**, *1935*), he has demonstrated the presence of the Dinaric race as a dominant element among the Kodagus of Coorg. Similarly Gordon T. Bowles and Mrs. Bowles on behalf of Harvard University carried out an anthropometric survey in the sub-Himalayan region from Kashmir to Sadiya, and in the interiors of Assam and Burma, during two years of intensive work (1934–36) in which measurements on 6,305 persons were taken, of which over three thousand were Tibeto-Burmese, over two thousand Indo-European, and the rest Austric-speaking peoples. Bowles' survey is the most intensive yet undertaken in any part of India, and anthropologists everywhere will eagerly await the results of their extensive research.

Besides the investigations on selected tribes and castes mentioned above, attempts at reconstruction of the racial history of India as a whole were also made by Frhr. von Eickstedt who led the German-Indian Expedition during 1926–29 for the Saxon State Museum of Ethnology of Leipzig. Eickstedt has published preliminary accounts of the results obtained by him during this Expedition in several papers (*Ethn. Anz.* **1**, 1928 ; **2**, 1929-30) from which it appears that he measured 3,000 persons belonging to various groups. Eickstedt's scheme of the stratification of races and cultures in India, which he put forward in 1933 (*Zeits. Morphol. Anthr.*, **32**), is the first serious attempt at reconstructing the racial history of this country since Sir Herbert Risley's thirty years ago. Eickstedt considered that the population of India is made up of three major groups: (I) The Weddid or the primitive Jungle folk consisting of a (*a*) Gondid or dark-brown wavy haired race, and a (*b*) Malid or black-brown curly haired

race; (II) The Melanids or the black-brown progressive people of the Southern plains which is again made up of a (*a*) Southern or Tamilid, and a (*b*) Northern Deccanid or Kolid races; and lastly, (III) the progressive New Indian or the Indid group, divided into a (*a*) brown graceful, and a (*b*) coarse light browned North Indian types. Of these, the Melanid race is the oldest and is the 'Indidised' descendant of the Indo-Negrid or the Eastern branch of the Great Negro race (*op. cit.*, p. 95); it may now best be described as belonging to the fringe of the Negrid and Europid races. Though no definite evidence is available, the flake cultures of the later Stone Age linked up with the Tumba Civilization of the Northern Congo area of Africa, may be associated with these Indo-Negrids, among whose descendants at the present day (but considerably Indidised) the 20 million Tamil people of the old Carnatic regions must be counted (*op. cit.*, p. 96). The second stratum is formed by the Weddids, a people of the hunting totemistic stage, who by mixing with the Melanids created the primitive Malid race. The third stratum is made up of the matriarchal plough-using Indids, who are a branch of the South Europid races and who dislodged the Weddids from the plains, followed by the half nomadic warrior herdsmen who brought Aryan language and culture into India and form today the upper layer of the population. To these major racial strata may be added some minor waves such as those of the Palæ-Mongolids, represented by the Mon-khmer people who entered from Indo-China during prehistoric times; the Turinids who came with the Huns and Turks from the time of Alexander's invasion to 1000 A.D. and the Orientalids, whose entry synchronized with the Moslem invasion during the last thousand years.

Eickstedt's account has the merit of consistency, his recognition of a South Europid race as the basis, and of the 'Oriental' race as an element, of the Indian population are certainly improvements on Risley's classification. Similarly his criticism of Risley's use of linguistic terms in a racial sense is entirely justified; but much of the force of this criticism is lost by his equating the Tamils with the 'Kolarian' tribes ('Kolarian' though now obsolete, was certainly linguistic in origin). Nor is there enough evidence to justify his treatment of the Tamils as a separate racial entity distinct from the basic strain found among other Dravidian speaking groups. One cannot also consider them as the mixed survivors of an ancient Negroid race who lost their language by coming in contact with the Dravidian speaking Indids—when it is recalled that the most ancient form of the Dravidian language as also the traditions and beliefs of the people are best preserved in the Tamil language and 'Sangam' literature, and the largest relics of the ancient Dravidian Civilization also occur in the Tamil land, viz., Aditanallur. There is likewise an absence of historical basis for the contention that the 'West-Brachid' type is to be attributed to Hun and Turkish

intrusions, and the part assigned to this race is very minor as compared to the rôle it has played in the racial formation of the Indian population.

A somewhat different reconstruction of the racial history of India was advanced by the author in the Ethnographical Volume of the Census of India (*Census of India*, **1**, pt. III, 1935), based on the measurements of 4,000 persons taken in connection with the Census operations during 1930–33. The statistical analysis of the data disclosed, that the basis of the Indian population in general, as Eickstedt also recognized, was a short dolichocephalic strain with high head and moderately broad nose, over which had superimposed a brachycephalic race of mostly plano-occipital type in Western and Eastern India, and a Proto-Nordic in North Western India; the advent of the latter synchronising with the invasion of the Vedic Aryans. In addition, the tribal groups revealed a definitely Negrito strain, now mostly submerged, and a Proto-Australoid element, which in combinations of various strengths, made up the aboriginal population, except in the sub-Himalayan regions and the hills of Assam and Burma where the Mongoloid races of both the long-headed and the broad-headed types formed the chief constituents of the population. Among minor strains the 'Oriental' race also certainly entered, specially in the North Western parts. Lastly an attempt was made to trace some of the racial strains present now-a-days to prehistoric times, and thus a picture of the racial history of India was envisaged in broad outlines.

(c) *Racial Biology.*

Of the various subjects coming under this head, a beginning has been made of late in the investigation of the difference in blood group proportions, vital capacity, basal metabolism and the rate of growth in children.

In blood grouping, L. and H. Hirzfeld are responsible for taking the first tests on Indians (*Lancet* **2**, p. 675, 1919). They examined blood samples of 1,000 Indian soldiers in Macedonia during the War and found that the highest percentage of Group B (41·2%) existed among them. Unfortunately the sample examined, was a heterogeneous one, composed of Gurkhas, Gharwalis, Jats and Rajputs and we have no means of determining how the proportion of different blood groups were distributed among the different races constituting this sample. Similarly the investigations of Bais and Verhoef (*Compte-Rendu de la III^{e} Sess de l'Inst Internat. d'Anthr. Amsterdam*, 1927) refer to Tamil coolies in the Sumatra tea gardens who came from various parts of S. India and Ceylon and belonged to different castes and tribes. In R. H. Malone and M. N. Lahiri's comprehensive survey on Indians the results were shown separately for the Baluch, Pathan, Hazara, Jat, Chattri and the Rajputs, but in the samples of 2,357 'Mixed

Hindus' from the United Provinces, and 589 'Dravidian' Tea-Garden coolies of Chota Nagpur, people of different castes and tribes were lumped together, and the results, therefore, are useless from the anthropological standpoint (*Ind. Journ. Med. Res.*, **16**, pp. 963–968, 1929). It is not surprising, therefore, that considerable differences are to be noticed in the relative percentages of 'O' and 'B' in the two Dravidian samples of Bais and Verhoef, and Malone and Lahiri, which, though included under the common designation of 'Dravidian' are racially very different. The researches of P. Tigueiredo on 309 Christians and 200 Hindus of Portuguese India (*Argv. Esc. Med-Cir., Nova Goa*, A, **10**, 1935), suffer from the same defect, as sect and race are not synonymous terms, and clearly bring out the danger of using linguistic and popular expressions in ethnical sense in blood group investigations. Fortunately the need for carefully discriminating between different tribes and castes, and of separately recording the results are being increasingly realised, and in the work of da Silva Correia (*op. cit.*, 1934) on 400 Marhattas and 100 Moslems (*op. cit.*, 1937) the ethnic groups were kept strictly distinct. Similarly in S. R. Pandit's investigations on the Todas (*Ind. Journ. Med. Res.*, **21**, 1934), A. Chaudhuri's on West Bengal Kayasthas (*Man in India*, **16**, 1936), and A. Aiyappan's on the primitive tribes of the Western Ghats (*Current Science*, **4**, 1936) the blood samples of each of the ethnic groups were separately studied and recorded. Equally satisfactory has been the work of E. J. W. Macfarlane (*Current Science*, **4**, 1936; *Man*, **37**, 1937; *Journ. Roy. As. Soc. Bengal*, N.S., **2**, 1937) who is conducting a very careful survey of blood groupings among Indian population in which all ethnic groups and castes are being separately considered. Her researches include tests on the Nairs, Syrian Christians, Black Jews, Illuvas of the Cochin State, Nepalese and Tibetan Lepchas from Kalimpong and several Bengali castes of Southern Bengal.

The results so far recorded in India do not justify any far-reaching conclusions as the materials on ethnically separated groups are as yet very scanty, but nevertheless they are fraught with some interesting possibilities. The preponderance of B over A appears to be an essential Indian condition with the exception of Cochin and the tribal groups of Southern India, and is not met with anywhere except among the Gypsies of Hungary and the aboriginal tribes of Shansi (W. China). Of these two, the Gypsies are known to have migrated from Northern India and have kept themselves as a distinct community. The highest percentages of Group B so far recorded from any part of the world, for separate groups occur among the cultivators of Lower Bengal, both Moslems and lower caste Hindus (40%), and among the Todas of the Nilgiri hills (38%). The frequencies of B ('q') in these, are 36·1, 28, 28·2, 27·2 and 30 respectively. Compared with the lower castes, the upper castes (except in Cochin), on the other hand, show a decrease in the percentage of B and an increase in the corresponding figure for O,

which is as high as that of Western Europeans. It is possible, therefore, that the locale of the origin of the mutation to B, occurs among the lower caste population of the Gangetic Delta or somewhere in the Chota Nagpur plateau from where the basic strain among these people might probably have been recruited. One of the important tasks, consequently, in serological enquiries in India will be to ascertain the exact focus of origin of mutation to B.

There are a few papers published on vital capacity, the earliest of which was by S. L. Bhatia (*Ind. Med. Gaz.*, **64**, p. 9, 1929) who found the average lung capacity of 100 Marathi students measured by Spirometer to be 3·091 litres. B. T. Krishnan and C. Varud (*Ind. Journ. Med. Res.*, **19**, p. 1165, 1931) found the same for South Indian males to be 2·86 litres, which are 73% and 67% respectively of the average for British and American men of the same height. A. N. Chatterjee's work on 2,500 Bengali students between the ages of 15–22 showed the average vital capacity to be $3{\cdot}01 \pm {\cdot}501$ litres or just about the same as that of the Marathi students (*First Studies on the Health and Growth of the Bengali Students*, 1932). E. D. Mason (*Trans. Eighth Congr. Far East Assoc. Trop. Med. Bangkok*, 1930 ; *Ind. Journ. Med. Res.*, **20**, pp. 117–134, 1932) who did similar work for women in South India, found the average of 853 subjects to be between 76 and 78 per cent. of the capacity for American women of the same height. Mason found that among the South Indian women, the Malayali showed a higher vital capacity than the Tamils and Telegus. She also calculated the surface area of the subjects whose vital capacity was taken, and found that the Vital capacity-surface-area-index for South Indian women is considerably lower than that of American women, but similar to that recorded among Chinese women. It would appear, therefore, that low vital capacity is more of a physiological than a morphological or racial trait, but more representative samples in which the castes and tribes are carefully separated, are required before a definite conclusion can be reached.

In basal metabolism the only investigation worth mentioning is that of E. D. Mason and F. G. Benedict (*Ind. Journ. Med. Res.*, **19**, 1931 ; *Amer. Journ. Phys. Anthro.*, **16**, 1932) on South Indian women students. They were found to have definitely low metabolism—being 17·4 p.c. below the standards for American women. This low metabolism of South Indian women may not improbably be due to their lower protein intake, as compared to that of American women.

Investigations made by W. R. Aykroyd and K. Rajagopal (*Ind. Journ. Med. Res.*, **24**, pp. 419–37, 1936), H. E. C. Wilson, B. Ahmed and D. D. Mitra (*ibid.*, **24**, pp. 817–37, 1937), and E. J. W. Macfarlane (*Current Science*, **5**, 1937), show that the height and weight of South Indian boys lag behind those of American, British and Bengali boys at all ages, but the growth curves for all Indian communities show certain similarities, except for the Sikhs,

who show a rapid acceleration in height and weight after the 11th year when they outstrip all other communities including the British. There is clearly a great field for these investigations and larger and more comprehensive samples are necessary in which not only tribes and castes are kept distinct, but subjects belonging to similar economic conditions are chosen.

V. Cultural Anthropology.

(*a*) *Arts and Crafts.*

In the general accounts of the tribes published, specially of Assam, there is usually a well-written chapter on material culture. Hutton and Mills' descriptions of dwellings, dresses, personal ornaments, domestic implements, weapons and modes of transport of the different branches of the Naga tribes, are exhaustive. Roy's later works on the Birhors, Bhuinyas and Kharias also include some accounts of the material cultures of these tribes. Similarly in Man's works on the Andamanese and the Nicobarese, there are excellent descriptions of the arts and crafts of these people. Brown also devoted a chapter (*op. cit.*, App. A) on the technical culture of the Andaman islanders and compared it with the cultures of other Negrito tribes like the Semangs and the Aetas of the Philippine Islands. By a careful study of the objects themselves he has come to the conclusion that the technical culture of the Great Andamans has undergone more changes than that of the Little Andamans, but aside from the introduction of iron, there is no evidence that the changes undergone have been due to outside influence. His contention that the outrigger canoe was acquired from some alien race is not supported by J. Hornell, who has shown in his monograph on Indian boats (*Mem. As. Soc. Bengal*, **7**, 1920) that alike in the form of the canoe, multiple beams used and the float connection, the single outrigger canoe used by the Andamanese must be considered to be a primitive form of that used by the Queensland aborigines of Australia and quite unlike that of the Nicobarese or any other known type. The conclusion, therefore, seems to be irresistible that the primitive single outrigger canoe originated with the Andamanese and travelled from there to Australia.

Marshall's work on the Karens also contains an excellent account of the arts and crafts of this interesting people.

Among individual items of interest, B. L. Chowdhuri published a short note on the Weighing Beam of Orissa commonly called 'Bisadanga' (*Journ. As. Soc. Bengal*, **11**, 1915), and N. Annandale on the Bismar Weighing Beam of the Darjeeling district (*Journ. As. Soc. Bengal*, **14**, 1918). There was a note on a musical instrument in the Shan States by H. S. Rao (*Man in India*, **8**, 1928). Reference may also be made to H. Balfour's tracing of the Naga hoe from bamboo field scrapers (*Man*, **17**, 1917), the account of the Ring

Gourd Hafting by F. J. Richards (*Man*, **32**, 1932) in which he showed that the holed-shaft principle in axe still survives in Southern India after the introduction of metals; and that of D. H. Gordon (*Man*, **32**, 1932) on the composite type of bow used by the Hunzas of Gilgit, which was shown by H. Balfour (*ibid.*, **32**, 1932) to be related to the type found in Central Asia, the Bashkirs of Eastern Russia, and suggested links with Persia.

Interesting notes were published by S. Nicholson (*Man*, **20**, 1920) on the significance of borders of 'Saris' used by Southern Indian women and by G. D. Walker (*Man*, **27**, 1927), on the bark-cloth manufactured by the Garos. Mention may also be made of the study of Nose Ornaments worn by Indian women by K. N. Chatterjee (*Journ. As. Soc. Bengal*, **23**, 1927) and on ornaments in general by R. Mukherjee (*Man in India*, **10**, 1930) and K. R. Pisharoti (*ibid.*, **11**, 1931). P. C. Basu made a detailed investigation of the Headdress of the hill tribes of Assam from specimens in the collection of the Indian Museum (*Journ. As. Soc. Bengal*, N.S., **25**, 1929), and N. Annandale was responsible for an excellent description of the mural decorations in the huts of an Oriya village in the Samal Island on the northern shore of the Chilka Lake. The designs on the huts in this village were mostly drawn from plant and animal lives and appeared to be decorative rather than religious in purpose, though some, such as the double-fish and footprints, were evidently lucky signs (*Mem. As. Soc. Bengal*, **8**, 1924).

A short note was written by G. D. Walker on Indian Boomerangs (*Journ. As. Soc. Bengal*, N.S., **20**, 1924), but a more critical and detailed study was published by J. Hornell (*Journ. Roy. Anthr. Inst.*, **44**, 1924), who in his comprehensive account of the Indian Boomerangs, blow guns and cross-bows showed that the former was derived from the same source as the ancient Egyptian ones, but whether they had also a common origin with the Australian weapon cannot be determined. The cross-bows of the Malabar coast are considered to be of European origin, but about the blow guns, of which there are three types in India, the author regards the Malayali form, in which a kind of harpoon is used as the dart, to be derived from the more primitive form of plain reed tube and simple dart found among the Kadars of the Annamallais hills. The wooden blow gun of the eastern coasts of Tanjore and Ramnad is, however, linked with the Indonesian weapon.

There are a few short notes published on fishing traps, such as those of S. L. Hora in the Kangra Valley (*Journ. As. Soc. Bengal*, N.S., **22**, 1926) and of B. N. Chopra in the Myitkyina district of Upper Burma (*ibid.*, N.S., **25**, 1929). The former is also responsible for a note on the crab-fishing in Lower Bengal (*Current Science*, **3**, 1935). For a comprehensive account of all the fishing methods of the Ganges we are indebted to J. Hornell (*Mem. As. Soc. Bengal*, **8**, 1924). Hornell considered all the methods employed in both estuarine and lacustrine fisheries, and classified them into three

main divisions, trapping devices, angling and netting, and regarded them as most elaborately devised, among which, with the sole exception of the 'China-net', now in use in Malabar and parts of Bengal and Assam, all the other devices are indigenous.

Attention was drawn by J. H. Hutton (*Man*, **30**, 1930; **31**, 1931) to the similarity of chank ornaments worn by Naga women, specially the Angamis and the Konyaks, to those described by Richards from the Iron-Age dolmens at Odugattur in the North Arcot district of South India (*Journ. Roy. Anthr. Inst.*, **54**, 1924) and attributed it to a South Indian intrusion in the Naga hills, but the true explanation of this resemblance was given eleven years before in J. Hornell's monograph on Chank Bangle Industry (*Mem. As. Soc. Bengal*, **3**, 1913), in which he showed from reference to classical literature and archæological finds that the industry now confined exclusively to Bengal, was at one time widespread from Tinnevelly to Kathiawar and Gujrat through a long chain of factories in the Deccan. The fragments of chanks unearthed by him at Kayal (Iron-Age site) in the mouth of the Tamraparni river, bore unmistakable evidence of their being cut by the same thin-bladed iron saw as it is done to-day in Bengal, proving that the Chank industry had a common source of origin and probably connected with the Northern Indian Buddhist cult which considered the chank to be one of the eight lucky signs and used as a sort of Talisman by Buddhist women in Tibet, the Chittagong hills, etc. from where it must have infiltrated to the Naga, Khasi and the Garo hills. Its general use in Bengal must also be attributed to the same cause.

B. Prashad published a short note on the Tigari (*Journ. As. Soc. Bengal*, **16**, 1920) or the burnt earthenware coracle of Eastern Bengal, but for the most detailed study of Indian boats we are again indebted to J. Hornell. In the two monographs published on the origins of the Indian Boat Designs, etc. (*Mem. As. Soc. Bengal*, **7**, 1920) and the Boats of the Ganges (*Mem. As. Soc. Bengal*, **8**, 1924), we have the most complete and comprehensive account of boats from any part of the world. From a critical and comparative analysis of the structure, shape and designs of Indian boats, Hornell came to the conclusion that they are of multiple origins. The primitive single outrigger canoe of the Andaman Islands is indigenous, but the more advanced type of Ceylon and Malabar coast is Polynesian in origin. The double outrigger on the other hand must have been introduced from Indonesia via Ceylon by the Shanars and Izhuvans, who probably also brought cocoanut with them. In the other ocean-going crafts, purely Arab designs prevail in the entire north-west coast from Cambay southwards to Bombay, from where local developments are noticed until in Malabar indigenous types of crafts again predominate. In the Tinnevelly district and along the entire eastern coast up to Orissa the Catamaran is the characteristic craft, derived from the Tamil word 'Kathemaram' or tied logs. From the simple raft of logs to the

most elaborately developed 'Kolamaran' or flying fish Catamaran on the Coromandel coast, Catamaran is the original South Indian craft and nowhere else has the raft idea evolved so much.

As far as the river crafts are concerned, they are strikingly and fundamentally similar in construction and design to those of ancient Egypt. Both the Indian and Egyptian types of crafts are similarly high sterned and low prowed and are steered by a single paddle. The Egyptian square sail, as well as the quarter steering paddle, are still retained in the large cargo boats on the Ganges and the use of the 'oculus' is exactly the same. Such similarities cannot be accidental or due to parallel developments but must have been introduced in India from Egypt by immigrants who also brought the wicker coracle and reed raft from ancient Mesopotamia.

(*b*) *Social Institutions.*

Reference has already been made to the mass of information, and in the works of Hutton, Mills and Roy, to the very detailed descriptions of customs and beliefs contained in the glossaries and monographs published on castes and tribes of India. In this section, only works on individual institutions, analyses of culture and general problems connected with acculturation and growth of culture are to be considered.

A considerable amount of investigation has taken place and a large number of papers published on social traits of the various tribes and castes of India, which supplied either new information or corrected and amplified accounts previously written. Among the latter may be mentioned the late L. K. Ananthakrishna Iyer's comparative study of the marriage customs of the Cochin State (*Journ. As. Soc. Bengal*, **10**, 1914); K. M. Panikkar's account of Nayar customs (*Journ. Roy. Anth. Inst.*, **48**, 1918); K. C. Viraraghava's paper on the variations in the customs of the Telegus and Tamils (*Journ. As. Soc. Bengal*, N.S., **19**, 1923), and G. Slater's analysis of the Dravidian element in Indian culture (*The Dravidian Element in Indian Culture*, 1924). Mention may also be made in this connection of K. P. Chattopadhya's attempt to deduce from evidence of coins and inscriptions (*Journ. As. Soc. Bengal*, N.S., **23**, 1927) the existence of mother-right and cross-cousin marriage among the Satakarni and Sunga ruling families of Southern India. Other papers deserving mention are K. Govinda Menon's account of the customs of the Kadars of the Cochin hills (*Census of India*, **21**, 1, 1933), G. Ahmed Khan's study of the Chenchus of the Hyderabad State (*Census of India*, **23**, 1, 1933), and L. A. K. Iyer's description of the customs of the primitive tribes of Travancore (*Pr. Ind. Ac. Sc.*, **4**, 1936). There is also an interesting note by E. H. Hunt (*Man*, **32**, 1932), on the Rafai Fakeers of Hyderabad. The most noteworthy contribution, however, is M. B. Emeneau's investigations on marriage regulations and taboos of the Todas of the Nilgiri

hills (*Amer. Anthr.*, **39**, 1937), in which he made many important corrections in the well-known account given by Rivers (*The Todas*, 1905).

On Central Indian tribes, mention may be made of D. N. Majumdar's investigations on the social and religious customs of the Hos of Kalhan (*Man in India*, **4**, 1924; *Journ. As. Soc. Bengal*, **20**, 1924; **22**, 1926; and **23**, 1927), and B. K. Chatterjee's accounts of the marriage ceremonies of the Bathurias of Mayurbhanj (*Man in India*, **9**, 1929) and the social institutions of the Kharias (*Journ. As. Soc. Bengal*, **26**, 1931). T. C. Das also published a study of the customs of the Kharias of Dalbhum (*Anthr. Pap. Cal. Univ.*, 1931) but for the most detailed and complete account of the Kharia institutions reference must be made to S. C. Roy's treatise on the Kharias already mentioned. S. S. Sarkar has published several papers on the customs of the Malers of the Rajmahal hills (*Man in India*, **13**, 1933; **14**, 1934 and **15**, 1935); N. Basu is responsible for a detailed account of the spring festivals of the Mundas (*Journ. As. Soc. Bengal*, **30**, 1924), and K. Mitra has given a careful survey of the marriage customs of Bihar (*Journ. As. Soc. Bengal*, **23**, 1927). W. V. Grigson's investigations of the Marias and other related tribes of the Bastar State (*Census of India*, **12**, 1, 1933) brought to light many interesting facts about these little known tribes of the Central Provinces. Similarly, C. S. Venkatachar's detailed description of the customs of the Bhils (*Census of India*, **20**, 1, 1933) of Central India supplied a mass of information hitherto unknown.

D. N. Majumdar has tried to interpret the data on the social institutions of the Korwas of the United Provinces according to the method of Malinowski (*Man in India*, **9**, 1929; **10**, 1930), and K. P. Chattopadhya has made an attempt to analyse the culture of the Newars of Nepal. The latter's investigations would tend to show the existence of a primitive hoe culture with terraced cultivation among the Newars, on which were subsequently added plough cultivation and the knowledge of the working of iron (*Journ. As. Soc. Bengal*, **19**, 1923). Other papers that deserve mention are P. C. Basu's account of the social and religious institutions of the Chakmas of the Chittagong hill tracts (*Journ. As. Soc. Bengal*, **27**, 1931) and T. C. Das' analysis of the culture-complex centering round the use of fish in Bengal (*Man in India*, **11**, 1931; **12**, 1932).

On the customs of the Assamese tribal groups, several important papers have been published by B. Bonnerjea on the Garos (*Anthropos*, **30**, 1935; **31**, 1936), and by J. H. Crace, A. H. Fletcher and J. P. Mills on the hill Katcharis, the Kukis and the Nagas respectively (*Census of India*, **3**, 1932). J. K. Bose's analysis of the Nokrom system of the Garos (*Man*, **36**, 1936) is also a valuable contribution. The most intensive investigations on the culture of a specified area, so far attempted in India, have undoubtedly been those of J. H. Hutton in the Naga hills. In a series of papers published (*Man in India*, **4**, 1924; *Journ. Roy. Anth. Inst.*, **28**, 1928; and *Man in*

India, **11**, 1931), Hutton has demonstrated the close affinities of the Naga culture and that of the Oceanian islands, in the worship of the baetylic stones, erection of stone monuments, the methods of the disposal of the dead and ideas of a future world and future life. In a recent paper he has carried these investigations further and suggested that the culture-strata of Assam hills, consisting of an Oceanic canoe-culture, a matrilineal megalithic culture and the more recent patrilineal culture of the Kayan and the Kuki, are best explained as due to 'migrations of cultures, if not of people, from some centre in or near the Indian Archipelago, one of which terminated in Assam' (*Pres. Add. Br. Ass. Sec. H.*, Sep. 1937).

The segmenting of Society into many endogamous groups or castes being the most striking feature of the social organization in India has naturally received the greatest attention. Most of the writers after Risley contented themselves with amplifying, and in filling in details of his theories rather than approaching the problem from a new standpoint. Such was done by B. N. Datta in his 'Das Indische Kasten system' (*Anthropos.*, **22**, 1927). Similarly G. S. Ghuriye (*Caste and Race in India*, 1931) agrees with Risley's view that the origin of the caste system is racial differentiation but emphasises the subsequent priestly manipulation of Brahmins in trying to preserve the purity of the 'Aryan' race. H. Rao (*Indian Caste System*, 1931) and N. K. Dutt also (*Origin and Growth of Caste in India*, 1931) accept, in the main, the views of Risley, though attaching some weight to the Code of Manu.

E. A. H. Blunt (*The Caste System of Northern India*, 1931) is however more inclined to accept Senart's theory of the original tripartite class divisions among the 'Aryans', and considers that caste developed in India as a result of miscegenation owing to shortage of women among the Aryan invaders.

R. Chanda (*op. cit.*, 1916) took up a somewhat different line and attempted to show from reference to Vedic literature, that while racial discrimination was the basis of caste, the discrimination was not so much between the Vedic Aryans and indigenes, as that existing between the blond Northerners forming the priestly, and the dark Mediterraneans forming the secular classes, within the Vedic Aryans themselves, as evident from constant reference to class wars between the priestly and military classes in Vedic literature, and the absence of intermarriage between the Brahmin and other sections of the Aryans. There is not enough evidence, however, to justify the assumption of a separate racial origin for the Brahmins, and in any case the ban on commensality is not explained, which along with the taboo on intermarriage, are the two essential features of the Indian caste system, and differentiate it from class divisions and guild systems found among several other ancient Indo-European peoples.

S. Rice (*Asiatic Review*, **25**, 1929) developing Oldenburg's suggestion, that the taboo on commensality was pre-Aryan, attempted

to explain that the Indian caste system was essentially pre- and non-Aryan in origin. B. Bonnerjea (*Ind. Antiquary*, **60**, 1931) while criticising Rice for his theory of the pre-Aryan origins of the caste system, agreed that the taboo on interdining was due to primitive superstition and magic. J. H. Hutton attempted a more comprehensive treatment (*Census of India*, **1**, 1933) of the subject and explained that the sentiments and beliefs which lay at the basis of caste were traceable to the belief in 'Mana' on the commensal taboo and segregation found among the Proto-Australoid and Austro-Asiatic population of India, and which became effective as a result of contact with the Dravidian speaking peoples. In his opinion, therefore, though the development of caste was post-Aryan in which 'Varna' assuredly played an important part in crystallising and perpetuating the institution, the essential ingredients which made the development of caste in its present form possible were undoubtedly pre-Aryan. Hutton's views are criticised by S. C. Roy (*Man in India*, **14**, 1934) who considers that evidence from the Austro-Asiatic people of Central India does not lend support to his views and the concept of 'mana' as found among these tribes is not the same as that existing in Hindu society. K. P. Chattopadhya (*Journ. As. Soc. Bengal*, N.S., **32**, 1936) also deals at length with the origin and growth of the caste system and the different theories that try to explain it. He considers that caste endogamy, caste hierarchy, as well as the ban on commensality did not develop in pre-Vedic India and thinks that Hutton's explanation of the basis of caste segregation in 'Mana' is negatived by his own admission that among the Naga tribes there is no bar on commensality and intermarriage with strangers who may not, however, ply their craft in the village. His conclusion seems to be that the caste structure arose as the result of hostile contact of two or more cultured races as they settled down among the primitive aboriginal population of India.

The position of the son, resulting from the various forms of marriage recognized in ancient Hindu society and its effect on kinship terms were discussed by K. P. Chattopadhya (*Man*, **22**, 1922), H. A. Rose (*ibid.*, **22**, 1922) and N. C. Sen Gupta (*ibid.*, **24**, 1924).

Regulations affecting marriage and the analysis of Indian social organization were the subjects of an important contribution by F. J. Richards (*Man*, **14**, 1914) who held that marriage with mother's brother's daughter in Southern India, was the outcome of a compromise as a result of economic forces between *Marumakkathayam*, and *Makkathayam* superposed by the Aryan invaders, in which the essential features of matrilineal inheritance were preserved under patrilineal forms. G. S. Ghuriye (*Journ. Roy. Anthr. Inst.*, **53**, 1923), dealing comprehensively with the data bearing on cross-cousin marriage with the exception of Assam, however, doubts the validity of Richard's explanation, as marriage with the mother's

brother's daughter occurs among the Nayars who followed the Marumakkathayam system. From the presence of cross-cousin marriage he inferred that dual organization must also have been prevalent in Southern India at one time. This was questioned by K. P. Chattopadhya in one of the most suggestive and interesting papers on social organization (*Pres. Add., Anthr. Sec., Ind. Sc. Congr.*, 1931), who showed from its absence in Melanesian islands that cross-cousin marriage need not necessarily be associated with the dual form of society when that resulted from the migration of a more cultured race into an isolated area inhabited by a people of inferior culture. The various types of kin-marriage and rules of inheritance resulting from the contact of different groups of father- and mother-right peoples in various parts of the world were reviewed and he showed how economic forces in conjunction with social and sexual requirements tended to make certain forms of marriage more frequent than others. The effects of the rules of incest were not merely permissive as Mrs. Seligman (*Journ. Roy. Anthr. Inst.*, **57**, 1927; **58**, 1928) tried to show, but rather compulsive with certain forms of marriage. Attention may in this connection be drawn to the views of T. C. Hodson (*Man in India*, **1**, 1921) who considered that the exogamic form of society best served to determine the place of children in society by regarding those born of marriage as a recognized institution, as reincarnations of the deceased members of the group, while those resulting from incestuous unions as not so. The explanation put forward by K. P. Chattopadhya of the origin of the dual and tri-clan organizations was somewhat different from that of J. H. Hutton (*Census of India*, **3**, 1, 1921) who held that in migrations of peoples, two exogamous clans usually went together to facilitate marriage and tri-partite divisions resulted from intrusion of a third group who come generally as conquerors.

(c) *Games, Folklore and Religion.*

Accounts of different forms of sedentary games have been published from time to time among others by H. C. Das Gupta, J. M. Datta and S. L. Hora. Das Gupta who has been responsible for the largest amount of work in this line (*Journ. As. Soc. Bengal*, N.S., **19**, 1923; **20**, 1924; **22**, 1926; **23**, 1927; **26**, 1930; **27**, 1931) showed from a comparative study of these games that in their migrations to different places they had undergone some local variations but in essential features remained unchanged though known under different names. J. M. Datta described mostly the sedentary games prevalent in Bengal (*Journ. As. Soc. Bengal*, **29**, 1933; **30**, 1934; **32**, 1936), while S. L. Hora recorded some of those current in the Teesta Valley (*Journ. As. Soc. Bengal*, **29**, 1933). The latter also supported Das Gupta in his view that the game of 'Gol-ekuish' of the Central Provinces was a variant of

'Pretoa' of Bihar (*Journ. As. Soc. Bengal*, **27**, 1931). J. Hornell is responsible for a detailed description of string figures of Gujrat and Kathiawar (*Mem. As. Soc. Bengal*, **11**, 4, 1932) and several papers have been published on Riddles by R. N. Munshi, S. S. Mehta, J. H. Knowles and S. C. Mitra (*Journ. As. Soc. Bengal*, **13**, 1917).

The monographs published on the different tribes and castes of India contain a large number of folk-tales and songs. Outside these, J. J. Modi was responsible for publishing several (*Anthropological Papers* **1–4**, 1916–26) and S. C. Mitra for over a hundred; folk-tales of which a few only, connected with Hydrophobia and Scorpion Sting (*Journ. As. Soc. Bengal*, **11**, 1915), Transference of Disease (*Journ. As. Soc. Bengal*, **13**, 1917), Agricultural Deities, Plant Lore, etc. (*Journ. As. Soc. Bengal*, N.S., **30**, 1934) may be mentioned here. F. H. Malyon (*Mem. As. Soc. Bengal*, **3**, 1914) collected the folk-tales of the Pushtu speaking peoples of the North-Western Provinces, and W. McCulloch (*Bengali Household Tales*, 1912) published a large number of household tales from the rural districts of Bengal. D. C. Sen (*The Folk Literature of Bengal*, 1920) showed how the folklore current in Bengal closely resemble those of Europe, and suggested that these probably migrated from India during the early Buddhistic times. The same author is responsible for publishing the rural tales collected by C. K. De by years of strenuous labours in the interior of the Mymensingh district (*Mymensingh Ballads*, 1–4, 1923–27). J. N. Gupta has also published a large number of children's tales from different parts of Bengal (*Sishu Bharati*, **1–8**, 1933–37). Mrs. Rafy (*Folk-tales of Khasis*, 1920) has written on the folk-tales of the Khasis and J. P. Mills on those of the Lhota Nagas (*Journ. As. Soc. Bengal*, **23**, 1927). R. E. Enthoven (*The Folklore of Bombay*, 1924) has recorded the folk beliefs and practices of the Bombay Presidency and C. De Beauvoir Stocks (*Journ. As. Soc. Bengal*, **21**, 1925) has investigated the folklore of the Lepchas of Sikkim and has published their myths of creation, Zoological myths and the myths concerned with the deeds of heroes, etc.

N. Tripathi (*Man in India*, **15**, 1935; **16**, 1936) has published an account of the Osas of Orissa. D. N. Majumdar has recorded some of the folk songs of the Hos (*Journ. As. Soc. Bengal*, **23**, 1927), N. Chakravarti a Vrata Story of Bengal (*Journ. As. Soc. Bengal*, **26**, 1930), C. von Furer-Haimendorf and J. P. Mills have given a very complete account of the significance of the sacred founder's kin among the Eastern Angami Nagas (*Anthropos*, **36**, 1936) and M. B. Emeneau (*Proc. Amer. Philosph. Soc.*, **77**, 1937) is responsible for an excellent review of Toda songs.

The most important study, however, on folk literature is that of P. O Bodding, whose three volumes on the Folk-tales of the Santals (1925–29) contain the most detailed and exhaustive accounts of myths and legends current among any Indian tribe.

On Magic and Witchcraft also a large number of papers has been published by S. C. Mitra (*Journ. As. Soc. Bengal*, **16**, 1916) and J. J. Modi (*op. cit.*, 1916–27). S. L. Hora (*Journ. As. Soc. Bengal*, **22**, 1926) has described how goats are employed in Central Provinces to drive out diseases. S. C. Ray (*Journ. Roy. Anth. Inst.*, **44**, 1914) has published a general account of Magic and Witchcraft of the Chota Nagpur plateau, while P. O. Bodding's (*Mem. As. Soc. Bengal*, **10**, 1925–27) studies deal more exhaustively with the practices of the Santals.

Accounts of the religious rites and beliefs of different tribes have been published in the monographs on these tribes and in current periodicals, such as the Journals of the Asiatic (now Royal) Society of Bengal, the Bombay Anthropological Society and Man in India, etc. Of the latter, J. J. Modi's studies of the Tibetan Prayer Wheel, (*op. cit.*, 1916) and Funeral Ceremonies of the Parsis (*Asiatic Papers*, **3**, 1927) deserve special mention. Mention may also be made of D. N. Majumdar's investigations on the death rites of the Hos of Kolhan (*Journ. As. Soc. Bengal*, **23**, 1927); S. C. Mitra's note on the worship of the Deity Jalpeshvara in North Bengal (*Journ. As. Soc. Bengal*, **27**, 1931); S. L. Hora's accounts of the worship and propitiation of wild animals and the Deities of Ola, Jhola and Bon Bibi in Lower Bengal (*Journ. As. Soc. Bengal*, **29**, 1933) and C. J. Bonnington's comparisons of the Ossuary Practices of the Nicobar islands with those current in the Naga Hills and Melanesia (*Man*, **32**, 1932). K. P. Chattopadhya has described the Chadak or the Hookswinging festival and its variants in different parts of Bengal (*Journ. As. Soc. Bengal*, **31**, 1935) and P. R. Rahmann is responsible for a careful study of the religious rites of the primitive people of the Central Indian highlands (*Anthropos*, **31**, 1936).

The rules regarding the Hindu ritual of the disposal of the dead as laid down in the Satapatha Brahmana have been explained in a very suggestive paper by M. Levin (*Man*, **30**, 1930). According to her interpretations the texts clearly imply the mummification of the body before its cremation, signifying that the body has to be first restored by mummification and then revitalized by fire.

As in social institutions, the most significant contributions in the analysis of Indian religious practices however are those of J. H. Hutton. In a series of papers on the religious beliefs in the Naga Hills (*Journ. Roy. Anthr. Inst.* **52**, 1922; **56**, 1926; **58**, 1928) he has shown that the idea underlying them is the fertilising power of the soul-matter, whose removal by decapitation is regarded as the surest means of ensuring a good harvest. This hypothesis was further developed by him (*Census of India*, **1**, 1933) and the association of the soul-matter with human sacrifice, ceremonial cannibalism, megalithic monument, *Pretyasila*, phallicism, reincarnation and totemism was demonstrated. In his opinion the doctrine of life-essence, which underlies not only the tribal religions, but, as shown

from the manifold survivals in Hinduism was the real religion of the people. Belief in Hagiolatry among the common masses in Europe, specially of the Southern and Eastern parts, is traceable to the same underlying philosophy, which must be considered as a very early step in the evolution of man's religious beliefs.

VI. Conclusion.

From the foregoing review of the progress made in different branches of Anthropology, it will appear that the most important works in Cultural Anthropology during this period are: (i) the detailed studies of J. Hornell on Indian technology, specially the origins and designs of Indian river- and sea-going crafts, (ii) the intensive researches of J. H. Hutton and J. P. Mills on the stratification of the cultures of the Naga Hills, (iii) P. O. Bodding's studies in Santal Medicine and Superstitions, (iv) S. C. Roy's investigations on the social organizations of the Austric-speaking peoples of the Central Indian highlands, and (v) K. P. Chattopadhya's analysis of marriage regulations as affected by contact of peoples.

In Prehistoric Archæology Sir John Marshall's great work on Mohenjo-daro is easily the most outstanding and its effects on existing ideas of the origins of Civilisation have been far-reaching. H. de Terra's survey of the Stone Age cultures of North-Western India has been equally important, as it laid for the first time a scientific foundation for our knowledge of the lithic industries and their sequences in this country.

In Physical Anthropology, R. B. Seymour Sewell and the author are responsible for publishing the first scientific account of the physical characters of India's prehistoric inhabitants. Reference may also be made to Joyce's analysis of Stein's data on the Frontier tribes, Biasutti's comprehensive treatment of the measurements taken by Dainelli in the Upper Indus Valleys and da Silva Correia's studies in Portuguese India. Frhr. von Eickstedt has furnished several new ideas on Indian racial origins, while the author's detailed studies on the racial affinities of the peoples of this country have made it possible to give a connected account of the racial history of India.

PROGRESS OF PSYCHOLOGY IN INDIA DURING THE PAST TWENTY-FIVE YEARS.

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CONTENTS

INTRODUCTION.

Psychology is the youngest of the sciences. In human affairs the objective world has all along received preference and that is why the objective groups of sciences have been the first to develop. Psychological truth can only be discovered through introspection, but to the normal mind an introspective tendency seems to be an undesirable trait. That is the reason why psychology has been so late in entering the domain of sciences.

Wundt first realized the importance of studying mental states under special experimental conditions as a separate science. When he was appointed to the chair of Philosophy in the University of Leipzig he devoted his attention to the fitting up of a laboratory for studying mental states. This, the first psychological laboratory in the world, was established in 1875. Wundt attracted to himself brilliant students from all over Europe and America, and soon psychological laboratories sprang up in different countries.

It took more than thirty years for this new psychological movement to reach India. In 1905 Sir Asutosh Mookerji included psychology as an independent subject in the post-graduate classes. Dr. (now Sir) Brojendra Nath Seal after consulting the courses of studies of different universities in Europe and America, drew up a syllabus in Experimental Psychology for the University of Calcutta.

The psychological laboratory in Calcutta was started in 1916, and Dr. N. N. Sengupta who had worked under Prof. Münsterberg in Harvard was placed in charge. Students trained in the Calcutta laboratory have been instrumental in spreading the new psychological movement throughout India. The University of Calcutta

opened its post-graduate classes in psychology in 1916 and its undergraduate classes in 1920. The Dacca laboratory under the charge of Mr. H. D. Bhattacharyya was started in 1921. The Mysore laboratory was started in 1924 under the guidance of Dr. M. V. Gopalaswami who had his training under Prof. Spearman in London. The Universities of Lahore, Patna, Lucknow and Benares followed suit and fitted up psychological laboratories.

Psychological movement in India

Since its inception the psychological movement has been making a steady headway in India. In 1925 the Indian Science Congress started a separate Psychological Section which has grown to be very popular. In the same year the Indian Philosophical Congress was started with psychology as one of its sections.

The Indian Psychological Association with its membership extending all over India was started in 1925, and in 1926 the Indian Journal of Psychology made its appearance as the official organ of the Association.

The Indian Psychoanalytical Society, an all-India society affiliated to the International Psychoanalytical Association, was started in 1922. It has done valuable work in training psychoanalysts and in popularizing psychoanalysis.

Another psychological movement of a popular nature has been started since 1928 under the auspices of the Indian Association for Mental Hygiene. The Mental Hygiene Association runs a Clinic at the Carmichael Medical College and Hospital, Calcutta. In 1935 a Child and Youth Guidance Clinic was started at the F.C. College, Lahore. Quite recently a psychological clinic has been opened by Dr. B. C. Ghosh at the National Medical Institute, Calcutta, and another by Mr. U. S. Gheba in New Delhi. A Parents' League has been started at Udaipur, Rajputana, recently.

In 1933 a Home for feeble-minded children was opened at Jhargram under the name of *Bodhana*. Since then it has shifted to Belgharia near Calcutta. There is another Home for feeble-minded European children at Kalimpong.

Efforts have been made and are still being continued by different workers to popularize psychology in India by means of public lectures, radio talks, popular articles, study classes, etc.

The present position of psychology in the different universities

The University of Calcutta has the biggest laboratory in Experimental Psychology in India. In the B.A., B.Sc. and B.T. courses psychology forms one of the subjects and in the M.A. and M.Sc. courses psychology is an independent subject. Efforts are being made to include psychology in the I.A. and I.Sc. courses.

In the University of Dacca there is a well-equipped laboratory. Psychology forms a subject in B.A. (Honours) and M.A. philosophy papers.

The University of Mysore has a fairly well-equipped laboratory. The University undertakes to teach the different branches of psychology in B.A., B.T. and M.A. courses. The new M.A. degree course in psychology is purely by research. The Mysore laboratory has been concerned chiefly with higher thought processes and the application of psychology to education.

In the University of the Punjab there is no separate department of psychology but psychology can be offered as a subject for the B.A. Honours degree. An M.A. degree can also be obtained in psychology after the Honours degree. Instruction is provided in a class conducted jointly by the Forman Christian College and the Government College, Lahore. The practical course is conducted at the Government College laboratory which is fairly well-equipped.

In Patna a laboratory has already been in existence since 1920 at the B.N. College. In the University of Patna there is no separate provision for a degree in psychology. Psychology is studied along with philosophy. A laboratory on a modest scale was started at the Patna College in 1935. The laboratory does not get any regular recurrent grant. Recently another laboratory has been started at the G.B.B. College, Muzaffarpore.

In the University of Delhi a separate paper in psychology has been prescribed for all the different examinations from the Intermediate to the M.A. There is however no separate department of psychology in this University; neither there is any laboratory.

Proposals are on foot to start a psychological laboratory in the University of Aligarh.

In the rest of the universities of India psychology forms a part of the course in philosophy and as yet has no independent existence.

II. Main lines of psychological research in India.

As in the West, so in India also, psychological research has flowed into certain more or less well-defined channels. In India there are workers in General Psychology, Educational Psychology, Social Psychology, Child Psychology, Abnormal Psychology, Industrial Psychology and Religious Psychology. When it is remembered that in most of the educational centres in India laboratory facilities are non-existent it is not to be wondered that the bulk of published papers refer to problems of a general and theoretical nature. A fair amount of first rate work has been done on the theoretical aspects of psychology on problems relating to consciousness, wish, emotion, instincts and allied themes.

Apparatus

Experiments requiring the use of apparatuses have been undertaken mostly by the department of psychology, Calcutta University. Next come the

Universities of Mysore and Dacca. At the B.N. College, Patna, under the able guidance of Principal D. N. Sen (now retired) some fine experimental work has been conducted with locally improvised apparatus.

A number of new *apparatuses* have been devised by G. Bose at the laboratory of psychology in Calcutta. The sand motor (35) has been utilized for the first time in the Calcutta laboratory to drive memory apparatus. An exposure apparatus with an original type of electrical escapement has been made. The instrument is suitable both for demonstration work and for research. An ergograph for recording movements of big muscles has been constructed. M. V. Gopalaswami and Gangadharan (69) have constructed an improved type of choice reaction apparatus. K. C. Mukherji (111) has devised an æsthesiometer having certain special advantages.

Workers and centres of work

Educational psychology has been very popular and has claimed the attention of a large number of teachers and psychologists. Since the introduction of the Bachelors' Training Course scientific interest in educational problems amongst teachers has been growing and a number of workers in this line come from the teaching profession. There are also professional psychologists attached to the different universities who are engaged in educational problems. Intelligence tests have appealed to the imagination of many and the output has been voluminous. A proper standardization of mental tests adapted to local conditions remains however as yet unachieved. Allahabad, Dacca, Calcutta, Lahore, Bombay, Madras, and Benares have all been vying with one another in devising and adapting intelligence tests.

A few of the lady teachers have done some work in child psychology as distinguished from educational psychology. The former subject has received a good deal of attention from workers in Bengal. Problems in mental deficiency have been claiming their special attention recently.

Most of the work in abnormal psychology has been done in Calcutta and at the mental hospitals at Ranchi. Investigations in this line have entirely been carried on by practising alienists.

Study in social psychology has been the favourite subject of the University professors at Lucknow, and much valuable work has been done on this subject.

Within recent years attention of the workers in India has been drawn to the great importance of industrial psychology. A good beginning has been made in Calcutta and actual field work has been undertaken with very encouraging results.

Vocational tests and guidance have also claimed attention of psychologists in Calcutta and other parts of India. The progress as yet is not marked. Criminal psychology has been studied to some extent in Calcutta and Mysore. Only a beginning has been made in this line.

Not much work has been done in animal and physiological psychology as yet in any part of India. Psychology of art and literature and psychology of religion have certain capable workers but the output has been rather small.

III. Specific Problems.

Scope of Psychology. Emotion. Instinct. Consciousness

Having given a brief summary of the main lines of psychological research in India we are now in a position to deal in greater detail with specific problems. The *aim and scope of psychology* have been reviewed and sought to be defined by N. N. Sengupta (143), H. D. Bhattacharyya (30), G. Bose (33), M. N. Banerji (4), H. P. Maiti (87) and A. Datta (51). Relation of psychology to other sciences has been discussed by A. S. Woodburne (152) and M. West (150). Some of the general problems of psychology have received original interpretation by Indian workers. The problem of *emotion* has been discussed by S. C. Mitra (98) from a new angle. According to him feeling constitutes the essence of mind. Every mind is a store of energy and minds differ from one another in their potentialities. The original fundamental feeling of mind is the feeling of harmony. Unpleasantness is the experience of harmony disturbed and therefore is later in its genesis than pleasantness. The yearning to go back to the original state of harmony is the death instinct and that to maintain it is the sex instinct. This fundamental yearning remains as an unconscious drive. The phenomena of *instinctive behaviour* have been studied by K. C. Mukherji (110), S. C. Mitra (101), N. S. N. Sastri (137), A. S. Woodburne (153) and others. A new *theory of perception* has been put forth by J. K. Sarkar (132). It is based on the idea of 'depression and release' and is an attempt to bridge the gulf between consciousness and unconsciousness. B. C. Ghosh (60), J. Prosad (126), H. P. Maiti (94), and S. Jalota (73) have attempted to explain the different aspects of the *conscious and the unconscious mental processes*. Indra Sen (139) has discussed the *concept of self* in an interesting manner. H. D. Bhattacharyya (31) has offered an explanation of personal identity. S. K. Bose (45) has attempted, from the result of his experimental and introspective studies, to demonstrate the affective basis and continuous character of the *sensory qualities*.

Illusions. Perceptions.

Problems of *errors and illusions* in the domain of perception have received considerable attention from Indian workers. G. Bose (34) has tried to show that in deep introspection perceptions tend to lose their characteristics. Their localization and specific qualities fuse with one another in an undescribable whole. He has also developed a new theory of illusions. According to him perceptions are determined by latent wish factors. The wish underlying a

perception determines the action-attitude attached to the perception. Unconscious action-attitudes resulting from repression affect perception and distort their true nature so that illusions arise. S. Jalota (74) has discussed the problem of error from a psychologist's point of view. Different problems in connection with the perception of *form and distance* have been experimentally studied by N. N. Sengupta and S. K. Bose (145), S. C. Mitra (99), M. Ganguli (58), and S. K. Bose and N. Kanji (46). S. C. Mitra's work (100) on *indirect visual perception* throws light on the differential sensitivity of the peripheral portions of the retina as regards perception of forms. He has further demonstrated that under certain conditions a field perceived monocularly appears brighter than the same field seen binocularly. The *touch sensation* has been carefully investigated by K. C. Mukherji (109), and S. Roy (129). M. N. Banerji (5) has given an interesting report of the phenomenon of *synæsthesia*. He has also studied the problem of *acuity of hearing* (6) in detail and has shown that the left ear hears better than the right one. A new phenomenon relating to *subjective brightness* (7) has been recorded by him. H. P. Maiti (88) has worked on the *discrimination of light intensity*. He has found a discriminative sensibility of brightness as fine as ·021. G. Pal (116) has been working on the effects of continuously increasing loads on *judgments of weight* under different attitudes. These experiments are likely to throw new light on Weber's law. No profitable experimental work has yet been done in the domain of feelings and emotions. A beginning has been made by M. Samanta (135) in this direction. A study of *æsthetic perceptions* has been undertaken by S. C. Mitra and R. N. Ghosh (102) to test G. Bose's theory of unconscious bodily references in æsthetic judgments.

Memory

A large amount of work has been done on *learning and memorization* but beyond certain minor points nothing new has evolved. M. V. Gopalaswami (68) tried to determine the correlation between learning-effort and psycho-galvanic reflex. H. P. Maiti (89) has made an interesting observation on certain unconscious mechanisms bringing about mental inhibition during the process of memorization. The correlation between memory and intelligence has been studied by H. P. Maiti (91), and S. Jalota (75), and that between memory and accuracy of observation by S. K. Bose (47). S. Sinha (148) has shown the characteristic nature of the learning curve of a feeble-minded child. M. V. Gopalaswami (65) has discussed the question of evidence of intelligence in motor learning. N. N. Sengupta and C. P. N. Sinha (144) have found variation in the output of mental work done in isolation and in group.

Reaction time. Reflexes

M. Ganguli and M. Samanta (59) have found the norm for *reaction time* for Bengali students to be ·178 which is definitely less than ·190 to ·220 sec. given by Titchener in his text-books. G. Pal

(117) has recorded the variations in reaction times under different attitudes. M. N. Banerji (8, 9) has made use of reaction time experiments to indicate intellectual and physical fatigue.

Study of *reflexes* both ordinary and conditioned and also study of behaviour have been undertaken but nothing new has been achieved. At the Mysore laboratory psychogalvanic reflex phenomenon in monkeys has been studied by M. V. Gopalaswami (67), and at the Calcutta laboratory S. Jalota and S. Patra (76) tried to effect the conditioning of the finger-flexion reflex. S. N. Roy (130) has dwelt on the importance of conditioned reflex in psychology. V. K. Krishna Menon (105) in his book 'A theory of laughter' has tried to prove that *laughter* is a demobilization of psycho-physical instinctive forces. M. V. Gopalaswami (66) has traced the genesis of laughter instinct in an interesting manner.

Child. Education. Intelligence

Child psychology has been investigated by Indian workers in its different aspects. The mental development of the child has been observed by G. Pal (118). The problem of language has been specially studied by I. Latif (85, 86). Pre-school children have been studied by O. Berkeley-Hill (13, 14), S. Jalota (81), G. Pal (119), and M. N. Banerji (11). The sign-language of the deaf-mutes has been studied by H. Banerji (2). H. P. Maiti (95) has made certain important observations regarding the education of the deaf-mutes. The play instinct in children has been the subject of observation by late Miss S. Ghosh (63). Miss K. Kasambi (84) has suggested a new technique for the mental testing of children. Interesting studies of children's drawings have been made by A. Datta (52) and E. W. Menzil (97).

The problems of *educational psychology* have been treated by numerous workers. New methods and improvements of old ones have been suggested but there has been no wide departure from the past. N. G. Apte (1) has considered the problem of adult education in India. I. Latif is now investigating the problem of adult literacy in the Punjab. The advantages of the objective examination have been pointed out by G. B. Bhattacharyya (29). A. K. Datta (53) has conducted experiments to test the reliability of the essay-type examination. D. D. Shenderkar (141) has reported certain interesting researches in education. The problem of arithmetic has been discussed by D. D. Shenderkar (142) and S. Jalota (77), and that of reading by M. West and H. Banerji (151). Professional judgment of learning has been studied by Pars Ram (124).

Intelligence tests have received the greatest amount of attention. The tests have been studied both from theoretical and practical standpoints by J. M. Sen (140), H. P. Maiti (90), S. Pal (120), G. Pal (118), Miss R. Ghosh (61), Miss S. B. Gupta (64), G. C. Chatterji (48), and others. Vernacular versions of different European and American tests have been introduced by C. Rice (128), V. V. Kamat (83) and S. Jalota (78, 79). Group tests have

been specially studied by P. C. Mahalanobis (106, 107, 108) and S. Jalota (80). The former has subjected the group test devised by him to statistical treatment and has found the reliability to be very high. S. Jalota has attempted a comparative study of intelligence scores in English and vernacular. Attempts for standardization of mental tests are being made at Calcutta, Patna and Lahore. An excellent summary of intelligence test work has been made by O. Berkeley-Hill (12) and H. P. Maiti (96).

Society. Religion. Art

Social psychology and *group psychology* have received efficient handling by R. K. Mukherji and N. N. Sengupta (115). J. Prosad (127) has shown the influence of unconscious punishment fantasies in the propagation of certain types of rumour. O. Berkeley-Hill (15) has discussed the problem of communal conflicts from the psychoanalytical standpoint. M. Sahani (131) has studied social character types and A. K. Wadia (149) has considered the principles of social organization. Contributions to the *psychology of religion* have been made by H. D. Bhattacharyya (32), O. Berkeley-Hill (16), K. C. Mukherji (114) and S. Sarkar (133, 134). R. Haldar (70, 71, 72) has brought out the importance of unconscious homosexuality and of castration idea as motives for *poetry and plastic arts* respectively. S. C. Mitra (104) has discussed the psychological basis of creation and appreciation of literature.

Industry. Fatigue

G. C. Chatterji (49), M. N. Banerji (10) and S. C. Mitra (103) have been stressing the importance of *industrial psychology* for some time past. A strong plea was made in 1934 at the 21st session of the Indian Science Congress in Bombay for organizing a central bureau of industrial psychology and efforts are being made at present for the realization of the scheme. The University of Bombay is considering the feasibility of starting a laboratory of industrial psychology. The Calcutta laboratory is being fitted up with suitable apparatuses for the study of different problems in industrial psychology. Some valuable work in this line has been done by M. N. Banerji. Working at the factories of the Bengal Chemical and Pharmaceutical Works, Ltd., in Calcutta and of Tata's at Jamsedpur, M. N. Banerji has succeeded in finding out an important and easy method of determining the onset of fatigue in workers. A simple apparatus like the vernier chronoscope is able to detect the changes. A well-known firm had its product psychologically appraised at the Calcutta laboratory recently. The possibility of improving business with the aid of psychological knowledge is being gradually appreciated by local industrial concerns and researches in industrial psychology are bound to bear fruit in the near future. Vocational psychology has also been receiving attention to some extent.

The *problem of fatigue* has been investigated by several workers at the Calcutta laboratory. S. Sinha and M. Ghosh (147) investi-

gated the influence of sensory stimulus upon muscular work. H. P. Maiti (92, 93) has studied the diurnal course of efficiency and the different types of fatigue curves. As already mentioned M. N. Banerji has observed the effect of fatigue on reaction time. Experiments are now being carried on in the Calcutta laboratory to note the peculiarities of the fatigue curve when groups of big muscles are involved.

Abnormality. Sex. Crime

In the domain of *abnormal psychology* valuable contributions have been made by psychologists in India. O. Berkeley-Hill has dealt with the different aspects of abnormality in children and the effects of parental behaviour on the mental constitution of the child (14, 18, 19). The familial treatment of the insane, treatment of psychosis by prolonged sleep, occupational therapy, the part played by the feeling of guilt in mental disorders and other problems of psychiatric interest have been discussed by him (20, 21, 22, 23, 24). J. E. Dhunjibhoy (55, 56) has studied the effects of sulphur injection in psychosis. He has also studied the incidence of dementia præcox among Parsees (54). J. N. Pacheco (122) has contributed to the study of the problems of sterilization of the unfit. He has written papers on pyknolepsy, suicide, etc. (123).

On the basis of his psychoanalytical case records G. Bose (36) has formulated a new theory of mental life. He has explained repression, ambivalence, conscience, imitation, projection, dream and many other mental mechanisms on the basis of a conflict between wishes of the opposite type (37, 39). He has evolved a new technique of psychoanalytic treatment by which mental symptoms are sought to be adjusted by fantasies of opposite types (38). The reliability of psychoanalytic findings has been discussed by him and specific psychoanalytical problems have received new interpretation in his hands (40, 41).

In *sexology* O. Berkeley-Hill (25, 26, 27) has contributed to the psychology of sexual reciprocity and birth control. He has also dealt with the subjects of sex hygiene and auto-eroticism. G. Bose (36, 37, 42) has discussed homosexuality, the ambivalent sexual traits, the nature of perfect love and the duration of coitus (44). He has also given an account of the concept of sex in psychoanalysis (42). S. Jalota and Miss D. K. Grewal (82) have written on kissing. K. C. Mukherji (113) has discussed sex in the Tantras.

In India there is a big field for work in *criminal psychology* but unfortunately no work of any importance has been done in this line. G. Bose gave a course of lectures to police officers under training at the Government Detective Training School on crime and psychoanalysis with special reference to Indian conditions. Psycho-galvanic tests for the detection of actual criminals from a group of suspected persons have been carried out at the Mysore and Calcutta laboratories. M. V. Gopalaswami has written a few papers on the subject.

History

The *history of psychology* in India beginning from ancient times has been ably worked out by N. S. N. Sastry (138). Pars Ram (125) has also written a short history of psychology in India. J. Sinha (146) has made valuable contributions towards understanding the psychological findings of ancient Indian philosophers. The psychological outlook in Indian philosophy has been stressed by G. Bose (43). S. C. Mitra has written an account of the progress of psychology in Calcutta. R. N. Ghosh (62) has published a history of the psychoanalytic movement in India. The place of psychiatry in India has been discussed by O. Berkeley-Hill (28) and J. E. Dhunjibhoy (57).

IV. Future.

Difficulties

Psychology in India is barely twenty years old. In the different universities it is still fighting its way to establish itself firmly among the other sciences. Besides the inherent difficulty of the subject-matter itself referred to at the beginning, external obstacles in the shape of prejudices, distorted outlook, etc. have to be overcome at every step. For example a view seems to be current among many scientists and others who should be expected to know better that psychology is only applied physiology and that its task is to study physiological processes and biological activities. Mind always works with the body so that every psychological situation carries with it a physical situation as well. For a professed psychologist to turn his attention to the physical side, to the neglect of the mental, is a gross violation of the first principle of scientific procedure. It is just like an avowed physicist concerning himself with the pleasure arising out of a tone rather than with the vibrations producing that tone. Philosophers also are not generally willing to co-operate with the modern activities of psychology and are inclined to look at them either with suspicion or disdain. Nevertheless psychology has made a healthy beginning in India and has already to its credit a fair amount of good solid work. It is true that till now psychological research in India has followed more or less beaten tracks, except perhaps in abnormal psychology, but the time is not distant when it will be able to open new paths for itself. The field is exceedingly rich and a good harvest awaits the earnest and intelligent worker. Much fruitful work may be done in folk and social psychology. In India different types of cultures ranging from the most modern to the most primitive exist side by side.

Unexplored fields

India's ancient learned men had a genius for introspective meditation and the Indian psychologist has that heritage. In this respect he enjoys an advantage over his colleagues in the west. If this faculty is properly cultivated problems requiring deep introspection such

as those of thought processes, higher cultural inhibitions, etc., will be successfully solved. The mystic experience of saints and Yogis should form the subject-matter of psychological research and India is the best place for this study. The Andhra University conceived of such a scheme but the project failed to materialize. The Board of Higher Studies in Psychology, University of Calcutta, has recently made suggestions for bringing the course in psychology up to date and it has proposed to include the study of Yoga in the syllabus.

Criminal psychology is another field likely to yield fruitful results but Government co-operation is necessary for this work. Industrial psychology offers vast opportunities for research in India. Comparative, genetic and abnormal psychology also have each dark regions waiting to be illuminated. It is up to the authorities of the different universities to foster the growth of the new Science of Psychology.

V. Bibliography.

The following abbreviations are used throughout:

A.J.P.	American Journal of Psychology.
Br. J.P.	British Journal of Psychology.
Cal. Rev...	Calcutta Review.
I.J.P. ..	Indian Journal of Psychology.
I. Med. Gaz.	Indian Medical Gazette.
Int. J.P.	International Journal of Psychoanalysis.
J.M.Sc.	Journal of Mental Science.
Phi. Quar.	Philosophical Quarterly.
Psy. Quar.	Psychoanalytical Quarterly.
Psy. Rev.	Psychoanalytic Review.
Psy. Stud. Myso.	Psychological Studies, Mysore Univer.
Quar. Bull. M.H.	Quarterly Bulletin of the Indian Association for Mental Hygiene.

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PROGRESS OF ZOOLOGY IN INDIA DURING THE PAST TWENTY-FIVE YEARS.

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Contents.

I. Preface.

[The authorship of this chapter was, in the first instance, offered to Dr. S. L. Hora by the authorities of the Indian Science Congress Association. Dr. Hora had invited the co-operation of zoologists working in India for writing up the chapter, and had obtained summaries of progress in various branches of Zoology from specialists on these branches. Owing to pressure of other work he felt that it would be difficult for him to complete the account of progress in Zoology before the appointed time, and, therefore, obtained the permission of the Executive Committee of the Indian Science Congress Association to hand over the unfinished part of the work to the present author. Although the work of writing up the present chapter had been entrusted to the author at a comparatively late period, the burden on his shoulders had been considerably lightened by the partly finished material which was placed in his hands. Nevertheless, the author is responsible for any errors and omissions in this chapter, and craves the indulgence of his readers, as he is well aware that work undertaken under short notice and consequently executed in a hurry is bound to be defective in many respects. Moreover, for a critical appreciation of the advances made in any science it is essential that every contribution should be examined in detail, and the author regrets that in the short time at his disposal it was impossible for him to do so. The summaries of progress by the following specialists on their own subjects have very materially assisted the author in writing up this chapter :—Dr. Vishwanath on Cytology, Dr. G. S. Thapar on Helminthology,

Dr. H. N. Ray on Sporozoa, Dr. H. S. Pruthi[1] on Entomology, Dr. S. L. Hora on Ichthyology, Dr. B. Prashad on Conchology, Dr. B. N. Chopra on Carcinology, Dr. K. N. Bahl on Morphology, and Dr. S. C. Law on Ornithology. The present author is, however, solely responsible for the parts dealing with Marine Zoology, Arachnology, Herpetology and Mammology, and partly for Protozoology, Morphology, and Entomology. To the specialists mentioned above, and to the indulgent Editor of this work the author is grateful for much valuable help. To these gentlemen and to Dr. S. L. Hora and the authorities of the Indian Science Congress the author's thanks are due.]

II. Introduction.

The aim of the present chapter is to appraise the progress of zoological research in India since the inauguration of the Indian Science Congress in the year 1914, but a review of this nature would be incomplete and unsatisfactory without a reference to the early progress of Zoology in the country. At the eighth session of the Indian Science Congress which met in Calcutta in 1921, the President of the Zoology section, Dr. F. H. Gravely, reviewed the progress of Indian Zoology from about the middle of the 17th century to the beginning of the present. The work of the zoologists in India during that period was of a pioneering kind, and embraced field surveys of limited scope, biological observations, and a wealth of new knowledge in regard to the taxonomy of various groups of the Animal Kingdom, more particularly of the Fish, Reptiles, Birds and Insects of the Indian Empire. The progress of Zoology in India during the two and a half centuries covered by the aforesaid review constituted a firm and broad-based foundation on which the superstructure of twentieth century zoological research was raised to considerable heights during the short period of a little over a third of the present century. The pace of progress was at first slow because of the paucity of workers. With the exception of the Royal Asiatic Society of Bengal and the Bombay Natural History Society which encouraged among their members the spirit of scientific enquiry in regard to subjects of natural history, there were no organized institutions to foster or stimulate the pursuit of zoological research. The only institutions of zoological research under official control were the Natural History Museums at Calcutta and Madras, and one or two colleges in the Punjab and the United Provinces. Among the science subjects taught in the few Indian universities at the beginning of the century, Zoology was the least important in but three of them, namely, Madras, Lahore and Allahabad. With the dawn of university expansion in the provinces of India which approximately coincided with the birth of the Indian Science Congress, Zoology came to occupy its rightful place amongst the science subjects taught in the universities.

[1] Dr. Pruthi was assisted in this work by other ;, viz., J. C. M. Gardner, S. K. Sen, and Dr. D. R. Mehta.

Thus the Universities of Agra, Aligarh, Benares, Bombay, Calcutta, Lucknow, Mysore, Nagpur, Osmania, and Rangoon which instituted degree courses in Zoology within the last quarter of a century, helped to quicken the pace of this progress, which is clearly reflected in the proceedings of the Indian Science Congress by the bulk of the papers read being contributions from research workers and teachers attached to the Zoology departments of the Universities. Apart from the increase in the number of universities teaching Zoology there has been expansion in the activities of scientific departments, Imperial as well as Provincial. Among these may be mentioned the Imperial Agricultural Research Institute (formerly of Pusa and now of Delhi), the Imperial Veterinary Research Institute (Muktesar), the Imperial Forest Research Institute (Dehra Dun), the School of Tropical Medicine and All-India Hygiene Institute (Calcutta), the Indian Lac Research Institute (Ranchi), the Indian Institute of Plant Industry (Indore), the Locust Research Institute (Karachi), the Imperial Sugar-cane Breeding Station (Coimbatore), the Helminthological Institute (Rangoon), the Zoological Survey of India (Calcutta), and the Madras Museum and Fisheries departments. The special problems of agriculture, of animal husbandry, of tropical diseases of man and animals, of fisheries, and of the geographical distribution of animals are studied by the departments concerned.

In a tropical country of the dimensions of India with its varied physical features and climate, and with Zoology as a young science in this country, progress, as may be expected, was chiefly in the direction of making known the faunistic elements of this vast area in relation to the types of environment present. Consequently our record of progress consists of considerable data in regard to the distribution of known species and to the new elements in the fauna which have been discovered from time to time in the course of the last quarter of a century. In the investigation of the fauna of this country, the predilections of individual workers, the special necessities of investigators attached to certain departments, the availability of zoological material in various centres of investigation, and a thorough acquaintance with the gaps in our knowledge of the fauna seemed to have influenced the course of zoological research. One of the causes which contributed to the expansion of our knowledge of the fauna of India has been the enthusiasm of investigators and specialists abroad who on a study of Indian material suggested lines for further work and pointed out the gaps in our knowledge of the Indian fauna. This stimulus from outside has been fruitful in many ways of which the publication of several volumes of the official *Fauna of British India* series is one. An extensive survey of the freshwater molluscs of India was prompted by the inadequacy of our knowledge of these animals, some of which, at any rate, are known or were suspected to act as vectors of human and animal schistosomiasis. The distribution, mutual relationships, morphology and life-history of this group of animals by Annandale,

Prashad, Rao and others are consequently better known than those of any other group of freshwater animals. The Indian and Burmese Oligochaetes which have been the subject of exhaustive study by Stephenson and Gates respectively for over a quarter of a century are equally well-known. The special interest of successive zoologists attached to the Indian Museum at Calcutta from Wood-Mason and Alcock to Kemp and Chopra in the Indian Decapod Crustacea is almost traditional. Our knowledge of the freshwater fishes of the Indian Empire, which was in a state of stagnation for several years after the publication of the works of Hamilton-Buchanan and Day, has been augmented considerably by the researches of Annandale, Chaudhuri, Hora and Mukerji. The biological factors governing the life of hill-stream fishes and their adaptations to changing conditions, and the trends of evolution in various groups of freshwater fish have received special attention at the hands of Hora in a long series of papers published within the last 16 years. The marine fishes of the Bombay coast have been studied by Fowler, Lele, and Spence and Prater in a series of articles. The life-long interest of Annandale in the fauna of freshwater lakes and brackishwater areas not only of India but of the whole of Asia has resulted in considerable advances of our knowledge of the groups of animals characteristic of these areas. Thus his own contributions on the Invertebrate groups of which he was a specialist, such as Porifera, Coelenterata, Polyzoa, Mollusca, and Crustacea (Cirripedia), and those of his scientific colleagues both in this country and abroad have materially increased our knowledge not only of the faunistic elements occurring in the lakes, backwaters, and estuaries of India but also of the biological conditions under which they live. A knowledge of the fauna of the Ganges and the Mahanadi systems and of the smaller streams in many parts of the country we also owe to his efforts. The tradition in regard to the study of the fauna of specific environments in relation to biological conditions is being followed by a number of workers in India, particularly those associated with the Zoological Survey of India of which Annandale was the founder. The growth of morphology in this country is closely associated with university expansion. Zoology teachers and students in the universities studying Indian types of freshwater and terrestrial animals locally available, or marine animals at first imported from marine biological stations in Europe and later obtained from the Madras Fisheries Department, found it difficult to follow practical text-books published in England or America, and a large number of morphological papers on Indian species began to be published. The keenly felt want of practical text-books to guide the Indian students led naturally to the publication of special memoirs, under the editorship of Bahl, on some of the commonest types of freshwater and marine animals. These memoirs form a land-mark in the history of Indian Zoology. The ease with which helminthic parasites

may be obtained from the common types of vertebrate animals dissected in class rooms and studied in the laboratory with the minimum possible equipment seems to have induced many workers in this country to take up the study of Helminthology. The result of this activity is seen in the publication of three volumes on Cestoda and Nematoda in the *Fauna* series within less than a decade, and of an important monograph by Sewell on all the known larval trematodes. Besides these there are numerous papers on the taxonomy and morphology of Indian helminths by various authors in N. India and Burma. The very large number of new species of Polychaeta discovered by the Chilka Lake survey gave an impetus for the collection and study of this group in several parts of India. The researches of Southern, Fauvel and Ayyar have added considerably to our knowledge of the distribution, habits and life-history of various species of Polychaeta occurring in India. The pelagic fauna of Indian seas, particularly of the Copepoda, Urochordata, Polychaeta, and Chaetognatha has received some attention, but the best known of these are the marine Copepoda some families of which have been dealt with in detail by Sewell. Our knowledge of the littoral fauna of a reef-bound coast has been extended by the labours of Gravely in his investigation of the fauna of the Krusadai Island in the Gulf of Manaar. With the cessation of deep-sea dredging by the R.I.M. 'Investigator' during the period under review, the series of valuable contributions on the deep-sea fauna practically came to a close, but the reports on material collected previously continued to be published. Of these, the concluding part on the regular Echinoids by Koehler and the two parts on the deep-sea Hexactinellid and Tetraxonid sponges by Dendy and Burton mark distinct advances in our knowledge of these groups. The Arthropoda, particularly Insecta, have received very considerable attention during the period under review. The taxonomy, distribution, morphology, bionomics, and life-history of Insects have been dealt with by numerous authors, the Diptera, Coleoptera and Odonata being the most widely studied. The large number of volumes in the *Fauna* series published during this period on these groups of Insects is an indication of the extent to which they have been studied. The Myriapod fauna of India has also received considerable attention at the hands of Silvestri, Attems and Verhoeff. The discovery by Kemp of a hitherto unknown species of Onychophora referred to a new genus, *Typhloperipatus*, within the confines of the Indian Empire and his contribution to the morphology and bionomics of this rare species constitute an outstanding advance in the history of Indian Zoology.

The advances in our knowledge of the Batrachians, Reptilians, Birds, and Mammals have been no less marked than those of the Invertebrates. The surveys of the avian and mammalian fauna of various parts of the Indian Empire organized by the Bombay Natural History Society have very materially increased our know-

ledge of the distribution, variation, habits, and taxonomy of these animals. Several volumes in the *Fauna* series which have been published in recent years, have embodied the results of the faunistic and other researches on the reptiles and birds of India.

Keen interest has been shown in recent years in the study of the problems of Cytology, more particularly gametogenesis, and several contributions dealing with the Golgi bodies, mitochondria and other cell inclusions by Vishwanath, Bhattacharya, and Subramaniam among others have been made within the last decade.

The study of physiology of animals seems to have attracted the attention of very few workers in India, and except for stray notes in the course of morphological studies of Indian species there is little that is worthy of mention. The recent papers of Pal and Prasad [1] on the effects of sugars on the frog's heart, of Das [2] on carbohydrate storage in Tunicates, of Reddy [3] on the physiology of digestion in a species of freshwater crab, and of Lal [4] on the physiology of the stink-glands of a Millipede (see also Honjo [5] on the physiology of the neuromuscular system of *Caridinicola indica*) seem, however, to indicate that the physiology of Indian animals will soon become a favourite subject for investigation by zoologists in this country.

III. Protozoology.

The scope of this section in the present account will be limited to such groups of Protozoa as have not been dealt with in the chapters on progress in Medical and Veterinary Sciences. The study of Protozoa in India seems to have attracted first the attention of the Parasitologists whose observations on diseases of protozoal origin in human beings and their domestic animals are of great value not only to the medical and the veterinary practitioners but also to the general Protozoologist. Interest in medical and veterinary Protozoology naturally led to investigations of the protozoan fauna in general. The literature on the former is considerable, and for fuller information the reader is referred to the chapters on Medicine and Veterinary Research in this volume.

The free-living forms of Protozoa which inhabit our fresh- and brackishwater areas have been studied in comparatively recent years, but owing, unfortunately, to the paucity of workers on this group the volume of work that has been done is insignificant. The important rôle that the Protozoa of soils play as causative agents of chemical changes which affect the fertility of soils has not yet been fully realized in this country. In regard to soil Protozoa,

1 Pal, R. K. and Prasad, S. *Journ. Physiology*, LXXXIII, 1935.
2 Das, S. M. *Ind. Zool. Mem.*, V, 1936.
3 Reddy, A. R. *Proc. Ind. Acad. Sci.*, VI, 1937.
4 Lal, M. B. *Curr. Sci.*, II, 1933.
5 Honjo, I. *Mem. Coll. Sci. Kyoto Imp. Univ.*, Ser. B, XII, 1937.

as far as the author is aware, only three papers have been published, by Sandon (1927) on the composition and distribution of Protozoa in the soil, by Madhava Rao (1928) on the protozoan fauna of Mysore soils, and by Chaudhuri (1929) on the protozoal content of certain soils in India. Husain (1935) has made a preliminary study of the soil Protozoa of Lahore.

Of the parasitic marine Protozoa reference will be made in the section of Marine Zoology (p. 360), but of the free-living marine forms such as the Radiolaria, Foraminifera, Heliozoa, etc. practically no work seems to have been done during the last quarter of a century. Nor is anything known about the free-living Amoebæ and Flagellates of Indian waters, freshwater or marine. Chatterjee (1917), however, contributed a note on a new free-living *Amoeba*.

It is, however, worthy of note that increasing interest is being evinced in the groups, Ciliophora and Sporozoa. The publication of a volume by Bhatia (1936) on the former group in the *Fauna of British India* series to be followed by another on the latter group by the same author is sufficient evidence of the steady progress of Protozoology in India. In the following few paragraphs a brief account of the work done on Indian Protozoa is given.

Bhatia and his associates, Gulati, Mullick, Cooper, and others have published between the years 1916 and 1935 a number of papers on the freshwater and parasitic Ciliate Protozoa of the Punjab and Kashmir, while Ghosh (1918–1929) has described various forms of Ciliophora from Calcutta including *Scyphidia*, *Balantidium*, *Opalina*, *Tokophrya* and *Podophryra*. de Mello, in a series of papers (1920–27), gave an account of the intestinal Protozoa of *Leucotermes indicola* and other forms of Termites. The same author (1930–1932) described the parasitic Infusoria of Portuguese India and Malabar from Amphibian hosts. Gulati (1933) gave an account of the multiplication of *Nyctotherus macropharyngeus*. Jameson (1925) described several interesting forms of Ciliates from the stomach of ruminants, while the contributions of Kofoid and his associates (1929–1935) include descriptions of Ciliates from the Indian Elephant, from *Bos gaurus* and *Bos indicus*, and a revision of the genus *Diplodinium*.

Numerous papers on the blood-parasites of small mammals, birds, and fish have been contributed by de Mello and his co-workers (1934–1937). Among these may be mentioned their studies of the blood-parasites, *Giardia*, *Plasmodium* and *Hæmoproteus* of Indian birds, of the sexual schizonts and merozoites of *Toxoplasma fulicæ* from the Indian Coot, *Fulica atra*, of Trypanosomids from Indian birds and fish, and of the Hæmogregarines of Indian eels and lizards. Pearse (1932) described a new *Trypanosoma* from the fish *Saccobranchus fossilis*.

Within the last few years (1932–1935) Ray and his associates, Mitra, Chakravarty and Das Gupta have contributed a number of papers on the morphology and taxonomy of various Coccidiid

Sporozoa. The morphological part of their work is referred to in another section (p. 408) of this article. The life-history of a new Cephaline Gregarine from Indian millipedes and the founding of a new family, Hyalosporinidæ, for such forms as possess a hyaline membrane to their spores, the genus *Stenophora* from Indian millipedes, the studies on *Conchophthirus lamellidens* including observations on the lunar periodicity in conjugation, the discovery of new Coccidiids (*Eimeria*, *Isospora*, etc.) from the gut of *Bufo* are among their more important contributions. Setna and Bhatia (1934) described for the first time some Gregarines from the intestine of the Bombay prawn, *Parapeneopsis sculptilis*. Knowles and Das Gupta (1934-1935) have studied the ciliate, rhizopodous, and sporozoan parasites of lizards and monkeys, while the latter author (1935) recorded a large number (42) of species of Protozoa from the rumen of the Indian goat, *Capra hircus*, thirteen of which were new records to India and six were new species or varieties. Pearse (1932) reported a new gregarine, *Steinina metaplaxi* from a crab. The genus was hitherto known only as parasitic in beetles.

The Indian Myxosporidian parasites seem to have received scant attention. The only paper published during the period under review on this subject is that of Southwell and Prashad (1918) on certain undescribed forms of *Myxobolus* and *Sphaerospora* parasitic on freshwater fish.

IV. Marine Zoology.

The study of marine zoology in India has for its background the history of individual workers whose energy and enthusiasm paved the way for a steady advancement of knowledge of the subject. The pioneer work of zoologists like Stoliczka, Anderson, Wood-Mason and Alcock during the half a century preceeding the birth of the Indian Science Congress laid the foundation for the solid structure of the study of marine zoology that we now see in India. The long residence of some of the early zoologists in India and their continued interest in biological work as members of a scientific society, the Asiatic Society of Bengal, at Calcutta influenced opinion in favour of an organized effort to investigate the conditions of life in the sea on the lines of the 'Challenger' Expedition. In 1871 a committee consisting of distinguished biologists such as Stoliczka, Blanford, Anderson, Wood-Mason and Oldham appointed by the council of the Asiatic Society of Bengal reported on the desirability of moving the Government of India to undertake deep-sea dredging in Indian waters. The Asiatic Society's advocacy supported by the leading zoologists representing the Royal Society resulted in the establishment in 1874 of a Marine Survey Department, and in the appointment of a surgeon-naturalist on the staff of the Survey. During the early days of the Survey, 1874–1881, Armstrong, the first surgeon-naturalist, found it impossible to put

into execution the scheme of deep-sea dredging for want of facilities to do so, but was able to collect material from shallow water up to a depth of 100 fathoms. The pioneer deep-sea biological investigation was, however, undertaken in the Andamans and Nicobars by Wood-Mason in 1872 as a deputy of the Trustees of the Indian Museum, Calcutta. With a complete deep-sea equipment provided on the marine survey vessel 'Investigator' several more or less successful hauls, about a dozen per season of 6 months, were made in depths ranging from a few fathoms up to 2,000 fms. between the years 1884 and 1898 in regions as widely separated as the Persian Gulf, Ceylon, Andamans, the coasts of Burma, and the mouths of the rivers, the Ganges and the Hughli. The material obtained was sufficiently large and interesting to merit study by specialists, and a series of separate monographs dealing with the deep-sea Indian fauna began to be published under the authority of the Trustees of the Indian Museum from 1898 onwards. The monographs dealt with such groups as Hexactinellid sponges, Madreporarian and Alcyonarian corals, Echinoderms, Fish and Crustacea.

Both the survey work and the marine biological work of the 'Investigator' were interrupted during the war of 1914-18, and when in 1920 the survey was resumed the arrears of work limited her trawling operations to only one or two per season. The surgeon-naturalists were, however, able to collect a variety of marine animals from the reefs and shores not far from the ship's anchorage. As dredging and trawling formed a subordinate branch of the ship's routine and occupied an insignificant part of the surgeon-naturalist's time a systematic survey of the planktonic organisms, especially surface-living Copepods, and of the hydrographic conditions was undertaken by Sewell, from the survey season of 1910-11 and continued with interruptions up to the time of his relinquishment of that office in 1925. It was during this period that a newly designed mid-water net was used (with promising results) for the first time in the history of the Marine Survey of India.

The investigation of the fauna of the littoral zone and the inshore waters of the Indian seas received also considerable attention at the hands of individual workers and public bodies. Some years after the 'Investigator' was at work, Anderson (1888-89) went on a collecting expedition to Tenasserim and the Mergui Archipelago in 1881-82. In the first decade of the present century the Gulf of Manaar was explored by Herdman on the Ceylon side and by Thurston on the Indian side, and in the Arabian sea Gardiner and Hornell investigated the marine fauna of the Laccadive and Maldive islands and the Okhamandal Coast of Kathiawar respectively. These general investigations on the marine fauna were supplemented by spasmodic observations on the bottom and mid-water fauna made in the course of experiments on trawling conducted along their respective coasts by the maritime provinces of India, namely, Bengal with the trawler 'Golden Crown', Bombay

with the trawler 'William Carrick', and Madras with the trawlers 'Lady Nicholson' and 'Lady Goschen'. The scientific reports based on the material collected by these trawlers are not comprehensive and include only stray notes on the various groups of animals scattered in zoological literature.

In the period under review, apart from the work of the 'Investigator', there has been only one important expedition namely, the John Murray Expedition on the 'Mabahiss' under the leadership of Sewell to the Arabian sea, which has made valuable contributions to our knowledge of the Indian marine fauna. The reports on the material obtained are being issued in parts.

The exploration of the shore and littoral fauna of the coasts of India and of the maritime lakes and backwaters has been done at various times by zoologists in India during the past 25 years. The notable among these regions are the salt lakes and estuaries in Bengal, the Puri coast, Chandipore beach and the Chilka Lake in Orissa, and in Madras, the Vizagapatam backwater and Waltair beach, the Ennur backwaters and Pulicat Lake, the Madras coast, the coastal region from Kilakarai in the Ramnad District to Tuticorin including Pamban, Rameswaram and Krusadai island, the backwaters along the West coast from Mangalore to Trivandrum and Cape Comorin, the Bombay coast from Karwar and Goa to Bombay, the vicinity of Karachi in Sind, and the coast of Burma near Mergui.

The progress of marine zoology in Europe, America and Japan has been in no small measure due to the enterprise of Governments, Universities, public bodies and associations interested in the development of the marine resources of their respective countries. Most maritime countries have one or more marine biological stations which encourage the study of marine zoology and attract scholars and students from various parts of the world. India with her extensive sea-board and a physically varied coast had no marine biological station until a few years ago when the Madras Fisheries Department organized a small station in the extreme south of India (since transferred to Ennur in the vicinity of Madras). The Indian Universities teaching Zoology had, until quarter of a century ago, to content themselves with the study of European marine types of animals imported from Plymouth, Port Erin or Naples, but the enterprise of the Madras Fisheries Department made it possible for Indian students to study marine types common along the Indian coasts.[1] It is not a little surprising that even

[1] The publication in India of a series entitled the *Indian Zoological Memoirs* on the lines of the memoirs published in England under the authority of the Liverpool Marine Biological Committee was the natural sequence of the increased use of Indian marine material by colleges and universities in this country. The series is edited by K. N. Bahl and includes at present three memoirs on three separate Indian marine types commonly available for study on the Indian coasts.

after quarter of a century of progress in marine zoology there are only two marine zoological research stations in the whole of India, namely, the one at Madras maintained by the University and the one at Krusadai in the Gulf of Manaar maintained by the Madras Fisheries Department. Judging by modern standards, neither of them fulfils the ideal conditions necessary for continuous all-round marine zoological research work. Schemes for the establishment of a marine zoological station in Port Blair (Andamans) in the centre of the Bay of Bengal which has been aptly called the naturalist's paradise, and in Karachi on the coast of Sind at the head of the Arabian sea under the auspices of the Government of India which were favourably considered had to be shelved indefinitely owing to the unfortunate continual financial stringency of the country.[1] In spite of these drawbacks the pace of progress in marine zoology has not been slow, and the quarter of a century that has passed since the birth of the Indian Science Congress has contributed material additions to our knowledge of the Indian marine fauna.

The only survey of importance of any particular marine or brackishwater area or biological unit that was brought to a successful conclusion since the birth of the Indian Science Congress was that of the Chilka Lake, a maritime lake on the Orissa coast of India below the delta of the river Mahanadi. Sewell and Annandale (1922) investigated the Hydrography and Invertebrate Fauna of Rambha Bay of this lake in an abnormal year. In this lake of undoubted marine origin a few freshwater forms have established themselves while the estuarine or backwater forms are characteristic of the fauna of the Gangetic delta and of the lagoons on the coasts of India. The occurrence of purely marine species in the lake is seasonal. The most striking features of the fauna of the lake are the abundance of individuals and poverty of species, and the extraordinary power of individual adaptability of the permanent residents to physical changes in their environment. Such animals as Rhizostomous medusæ and Oxystome crabs for example living in the lake are capable of flourishing in freshwater at one season and salt-water in another. The fauna has, however, the representatives of nearly all the phyla except the Echinodermata. The main object of the Chilka Lake zoological survey as stated by Annandale was 'to lay a foundation for the study of the fauna of brackish

1 Recently the Indian Science Congress at Patna (1933) sponsored a discussion by biologists on the necessity of establishing a marine biological station in India, but the discussion turned towards the comparative merits of various places on the coasts of India as the most suitable as a centre of marine biological research work, but there was a general agreement amongst biologists that the establishment of an All-India Marine Biological Station was an urgent need. There is certainly room for more than one marine biological station in India, provided that funds are available, but the establishment of a Central Marine Biological Institute has been long overdue.

water and of water of variable salinity on the coast of India on the same lines as our predecessors in the Indian Museum have done for that of the abyssal fauna of Indian seas '. That this foundation was truly and well-laid is borne out by the fact that a considerable number of papers dealing with the elements of the fauna of the brackishwater areas along the coasts of India has been published in India since the Chilka survey was completed. The chief zoological interest of such investigations lies in the fact that brackishwater areas, particularly the estuarine regions, act as a highway for the penetration of certain marine elements which finally establish themselves in freshwater. The surveys of the Calcutta Salt Lakes and the Lower Bengal estuaries, the Vizagapatam backwater and harbour, of the Ennur, Pulicat, and Adyar [1] backwaters near Madras, and of the backwaters of the West coast of India which, when the results are published in a connected form, will show not merely the peculiar composition of the fauna but also the extent of the penetration of marine forms into waters of highly variable salinity.

The fauna of the sandheads at the mouth of the river Hughli has in recent years received some attention thanks to the interest of the members of the Bengal Pilot Service who send their collections of animals from depths of about 20 fathoms to the Indian Museum for study. Notes on some of the interesting animals, particularly fish and crustacea, from this collection have been published in Calcutta from time to time.

Our knowledge of the plankton of the Indian coasts is still very meagre, but valuable contributions have been made during the period under review by Hornell and Nayudu (1923), and by Aiyar, Menon, and Menon (1936), and Menon (1931) who studied the seasonal variation of the planktonic elements along the west and east coasts of Southern India respectively. The general features of the organic cycle and the seasonal variation of the plankton in tropical seas seem to be the same as those of the temperate seas, except that there is an appreciable difference in the elements of the planktonic fauna.

The zoological survey of the Krusadai Island in the Gulf of Manaar under the leadership of Gravely (1927) added another important contribution to our knowledge of the marine fauna of a reef-bound island subject to strong currents and to the monsoon winds. The results are, however, not so complete as those of the Chilka survey. An attempt to study the fauna of the Manora Shoal in the vicinity of Karachi on the same lines has been made by the University of Lahore under the guidance of Matthai.

In the field of geographic and oceanographic research in Indian waters Sewell's monograph 1925–1929 on the subject has been the most outstanding contribution to the study of physical conditions

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[1] Panikkar, N. K. and Aiyar, R. G. (*Proc. Ind. Acad. Sci.* VI, 1937) have given a detailed account of the fauna of this area.

under which the marine fauna exists. It deals mainly with the geography, the nature of the sea-bed and its deposits, the temperature and salinity of the coastal and surface waters, of the Andaman sea in relation to the adjacent waters like the Bay of Bengal and the Laccadive sea, and with the marine meteorology of the Indian seas as a whole. It shows conclusively that the physical conditions of the sea are in an almost continuous state of flux due to influences both within and without its geographical limits, and must be effecting profound changes in the character of the fauna, and that the study of the physical conditions is an integral part of the study of the bionomics of any given arm of the ocean or the sea whatever its size or geographical position.

The biological factors affecting the life of animals inhabiting the Matlah river, near Port Canning, Lower Bengal, have also been the subjects of study during this period of 25 years. The observations of Stoliczka and Annandale have been supplemented by those of Kemp and Pearse in recent years. Kemp's (1917) investigation of the fauna of this tidal creek of the Gangetic delta with water which is always turbid and of variable salinity showed the remarkable resemblance of many species of animals, especially among the fish and Decapod crustacea living in the creek, to the deep-sea forms. The resemblances were in most cases very superficial as for instance in colour, in outline, and in the presence of elongated filamentous appendages with a sensory function, but some species had morphological relationship to deep-water species as well. The very soft muddy bottom and low visibility which are the common physical factors of the bottom of a creek like Matlah and of that of the deep-sea have brought this convergence resulting in the resemblances noted above. Pearse's (1932) observations on the ecology of this creek dealt with the slow invasion of freshwater by marine animals, particularly of fish and crabs, and with their feeding habits. He thought that 'habitatic segregation', in other words, the avoidance of competition by invading unused areas, was the most important factor in the invasion of freshwater areas and land by marine animals through the media of estuaries and creeks like the Matlah.

So much for the general advancement of marine zoology in India. It will now be convenient to deal with the additions to our knowledge of the various groups of the animal kingdom beginning with the Protozoa and ending with the Vertebrata.

Protozoa.—The only papers of any importance published on the marine Protozoa during the period under review were by Setna and Bana (1935) on the new Coccidium, *Eimeria harpodoni*, from the Bombay Duck, *Harpodon nehereus*, and by Setna (1931) who described three new Sporozoan parasites belonging to as many new genera (*Bhatiella*, *Ferraria* and *Extremocystis*) from the intestine and coelomic cavities of Polychæte and Gephyrean worms from the Andaman sea. The characters of only adult trophozoites are known.

Porifera.—Our knowledge of the marine sponges of India after Schulze's report on the Hexactinellida of the 'Investigator' and Carter's papers on Tetraxonida is due to Annandale (1914, 1915), Dendy (1926), Kumar (1925), Burton (1928 and 1932), and Burton and Rao (1932). Annandale studied the Clionid sponges common on oysters, mussels and other molluscs, and the sponges parasitic on them, and gave an account of the biological differences of the sponge-fauna north and south of the Palk Straits connecting the Gulf of Manaar with the Bay of Bengal. Kumar, Burton and Rao advanced our knowledge of the sponges of the Indian Littoral, while Dendy and Burton made several interesting additions to our knowledge of the deep-sea forms. The interesting alga-like Euceratose sponge, *Cryptospongia enigmatica* from a depth of 1,045 fathoms, and the peculiar Spongiid, *Stenospongia aligera* from Mergui (65 fathoms) with a chitinoid cuticle and the pores restricted to the undersurface of a number of lateral wing-like processes are among the forms described.

Coelenterata.—Some notable additions by various authors have been made to our knowledge of the marine and brackish-water coelenterates during the period under review. Ritchie (1915) described the remarkable and peculiar new brackishwater Hydroid, *Annulella gemmata*, with an alternation of free and fixed stages in the vegetative hydroid phase and the singular method of multiplying itself by setting free planula-like buds and by a mode of transverse fission associated with the chitinous basalbulb. Lloyd and Annandale (1916) studied the life-history of *Campanulina ceylonensis* (Browne), the medusoid generation of which was known to occur on the coasts of Ceylon and Burma, in the Gulf of Manaar, in the Chilka Lake, and in brackishwater ponds and channels at Port Canning and Calcutta respectively, and discovered the hydroid stage which is still known only from brackishwater. Leloup (1932) gave an account of the marine hydroids from various parts of the Indian coasts and seas. Menon (1930, 1932) made contributions to our knowledge of the Scypho- and Hydro-medusæ from the Madras coast while Rao (1931) described the forms of Scyphomedusæ common in the Bay of Bengal and the Arabian sea. Recently, Stiasny (1937) recorded the occurrence of several species of Scyphomedusæ not hitherto known from the Arabian sea, and remarked on the general poverty of these medusæ in an increasing measure from the Malayan seas to the Arabian and E. African seas. Annandale (1915) described the new brackishwater genera of Actiniaria, *Phytocoetes* and *Pelocoetes*, from the Chilka Lake and the Gangetic delta. Menon (1914, 1926), studied the larval forms of certain Actiniaria at Madras and established the identity of *Anactinia pelagica* with *Cerianthus*, *Zoanthella* with *Sphenopus*, and of *Zoanthina* with *Zoanthus*. Carlgren (1925) proposed a revision of the Actiniaria of the Chilka Lake described by Annandale and suggested the creation of a new family, the Nevadneidæ, for

the reception of *Gyrostoma glaucum* Ann. and the inclusion of *Phytocoetes chilkœus* Ann. and *Halianthus limnicola* Ann. in the Halcampid genus *Mena*, and of *Phytocoetes gangeticus* Ann. and *Pelocoetes exul* Ann. in the Halcampactiidæ. Panikkar (1935–37) has added considerably to our meagre knowledge of the structure, bionomics, and systematics of various brackishwater and marine Actiniaria from the Madras coast. The contributions of Gardiner (1929) on the deep-sea Indian corals of the genus *Flabellum*, of van der Horst (1931) on the Indian solitary corals, of Matthai (1924) on the Madreporarian corals, particularly the aporose forms of the family Astræidæ, of the Indian seas have added considerably to our knowledge of the coral fauna of Eastern waters. The discovery of the coral, *Cylicia smithii*, Milne Edw. and Haime, in a sub-fossil condition in the Chilka Lake is noteworthy. Hornell (1922) brought together several interesting facts regarding the commensals of some Indian Alcyonarians, while Hamid (1931) recorded the occurrence of *Virgularia gracillima* Koelliker in the outer channel of the Chilka Lake. Hickson (1937) brought evidence to show that *Umbellula huxleyi* has not only a wide range of distribution, but that many so-called species are only growth stages or varieties of this species.

Platyhelminthes.—Southwell (1930) and Poche (1926) made valuable additions to our knowledge of the helminthic parasites of various marine animals from the Pearl Banks, Ceylon, and the Chilka Lake. These parasites belong to the genera *Rhynchobothrium*, *Otobothrium*, *Phyllobothrium* and *Tetrarhynchus*. Faust (1927) described the very curious new Holostome *Cleistogamia holothuriana* (from the intestine of the Holothurian, *Actinopyga mauritiana*, from the Andaman sea) which had to be accommodated in a new sub-family, Cleistogamiinæ, erected by him. This Holostome has no external genital openings with the result that self-fertilization is obligatory, and the eggs have a long polar filament. The intermediate host is believed to be a marine mollusc. With the exception of *Aspidogaster*, this is the only other instance of a fluke developing normally to adulthood in an Invertebrate. The creation of a new family, the Filisomidæ, among the Acanthocephala fell to the lot of van Cleave (1928) who described *Filisoma indicum* (gen. *et* sp. nov.) from the intestine of the fish *Scatophagus argus* from the Chilka Lake. The extreme length of the body and the proboscis, the curious location of the brain and the genital orifice, near the posterior end of the body, and the peculiar form of the cement glands made the creation of a new family necessary. Wheeler (1937) described the new Palæonemertid genus, *Nannonemertes* (*N. indica*), which is closely allied to *Pelagonemertes*.

Chaetognatha.—Of this group the only papers of importance are those by John (1933, 1937) who gives an account of the *Sagitta* of the Madras coast and of the seasonal variations in its distribution,

and by Lele and Gae (1936) who deal with the common *Sagitta* of the Bombay Harbour.

Brachiopoda.—Awati and Kshirasagar (1935) studied the distribution of *Lingula* sp. on the Bombay coast.

Polyzoa.—Our knowledge of this group we owe to the labours of Annandale (1915) and Robertson (1921) who gave an account of the forms occurring in the Chilka Lake and other brackishwater regions and at depths up to 1,000 fathoms respectively. The latter recorded the occurrence of *Membranipora* in brackishwater.

Echinodermata.—During the period under review the Echinoderms of the Indian seas received considerable attention. Koehler (1927) completed his monograph on the regular Echinoids. Clark (1932) gave an account of the Indian Crinoids of the super-families Comasterida, Mariametrida and Tropiometrida, and described the new Antedonid *Repometra arabica* from the Arabian sea. Bomford (1913) dealt with the deep-sea Ophiuroids from the Bay of Bengal and the Arabian sea. Clark (1936) found from his studies an increasing poverty of Crinoid forms from the Malay archipelago to the Arabian sea and the E. African coast of the Indian ocean, an observation which is in accord with those of Ekman (1935) in his 'Tiergeographie'. Setna (1931) made a detailed study of the Indian *Trichaster* and provided a key to the species. The interesting new Cidariid, *Phyllacanthus forcipulatus*, was recently described by Mortensen (1936). Aiyar (1935) studied the early development and metamorphosis of the tropical Echinoid, *Salmacis bicolor* Agassiz, in regard to external and internal structures and demonstrated the absence of sexual periodicity.

Annelida.—The foundation for a sound knowledge of the Indian marine and brackishwater Polychæta was laid in the quarter of a century after the inauguration of the Indian Science Congress. Southern (1921) described several new forms from the Chilka Lake while Fauvel (1932) rendered a comprehensive account of over 300 species belonging to 30 families of the Indian coastal and deep-water regions. He found the coastal fauna richer than the deep-sea fauna as may be expected from the varied conditions of the former, and the brackishwater forms peculiar. The best represented families are the Aphroditidæ, Nereidæ and Eunicidæ with more than 35–40 species in each. The Indian fauna does not materially differ from that of the Red sea, China seas, and the Pacific ocean, many species being cosmopolitan. Augener (1926) gave an account of the Ceylon Polychæta based on collections of Prof. Plate and others. Bindra (1927) contributed a short study of the genus *Eurythoe* based on material collected at Karachi. Gravely (1927) gave an account of the Polychæta of the Krusadai Is. in the Gulf of Manaar, while Aiyar (1933) published his studies on the brackish-water and marine Polychætes of the Madras coast and their larval forms. Aiyar (1931) also gave a complete account of the development and breeding habits of the Madras brackishwater

Polychæte, *Marphysa gravelyi* Southern. Of the Hirudinea, Kaburaki (1921) and Harding (1927) described several interesting marine and brackishwater forms parasitic on sharks, rays, globe-fish, Bombay-duck and mud-turtles. Aiyar and Panikkar (1937) recorded their observations on the swarming habits and lunar periodicity of *Platynereis* sp. from the Madras Harbour. They observed an interval of three lunar months between successive swarms and that swarming took place at maximum high tide during new moon.

Gephyrea.—Our knowledge of the Echiuroids and Sipunculoids of Indian waters is due almost entirely to the researches of Annandale and Kemp (1915), of Prashad (1919, 1935), and of Awati and Deshpande (1935), several new and interesting forms having been recorded within the last quarter of a century.

Pycnogonida.—The Indian littoral forms were studied by Calman (1923). Seventeen species were recognized of which ten proved to be new. Since Calman's report on this collection Raj (1927) described a new species from the Krusadai I.

Crustacea.—In regard to this group several notable advances have been made as a result of the labours of research workers stationed in India. In a period of about twelve years, Kemp (1914–1925) contributed an important series of papers on the Decapoda and Stomatopoda dealing with various marine and brackishwater forms of the Indian coasts, estuaries, and back-waters belonging to the families Hippolytidæ, Crangonidæ, Hymeno-somatidæ, Disciadidæ, Palæmonidæ, Ocypodidæ, Pasiphæidæ, Stylodactylidæ, Rhynchocinetidæ, Pandalidæ, and Anchistiodidæ in which are included species of the most varied habits. Kemp (1916) recorded for the first time two genera of Cumacea *Ophinoe* and *Paradiastylis* from brackish and fresh waters in the Chilka Lake. He was also the first to show that the curious resemblance of certain estuarine Caridean species inhabiting the bed of the Matlah river in Lower Bengal to certain deep-sea forms belonging to the family Nematocarcinidæ was due to the similarity in the physical conditions of life. The interesting associations which members of the sub-family Pontoniinæ form with other marine animals of the groups Porifera, Coelenterata, Echinodermata, Lamellibranchia, and Ascidiacea have been dealt with in detail. Chopra (1923) contributed a monograph on the Bopyrid Isopods parasitic on Indian Decapod Macrura, discussing their affinities with those of the Atlantic coasts of America. He (1930–1935) also contributed several articles dealing with certain new forms of Hymenosomatid crabs from the Indian coasts and backwaters, and with Decapod Crustacea living in the cloaca of Holothurians, and enlarged our knowledge of the Stomatopod and Decapod fauna of Sandheads at the mouth of the Hughli river. Odhner (1923) described certain Stomatopods from Ceylon and revised certain genera of Xanthid crabs of the Indo-Pacific area. Menon (1933)

described the life-histories of the Madras Decapods belonging to the families Sergestidæ, Callianassidæ, and Hippidæ. Our knowledge of the Indian Amphipods, Isopods, Mysids and Tanaidacea within the last quarter of a century we owe to the researches of Tattersall, Chilton, and Barnard. Tattersall (1914) recorded the occurrence of the only known Mysidæ in India—all from brackish-water—belonging to 3 distinct genera, one of which, namely, *Indomysis*, proved to be new. He (1922) gave an account of the Indian Mysidacea from the Gulf of Manaar and the Andamans and pointed out their Mediterranean affinities. Chilton (1920) recorded the occurrence of the marine Amphipod, *Ampelisca pusilla*, (known till then only from Norway, Australia, Ceylon, and the Chilka Lake in India) in the Ganges as far high up as Buxar, 500 miles from the sea. Barnard (1935-36) made considerable additions to our knowledge of the Indian littoral, deep-water, and brackishwater Amphipods, Isopods, and Tanaidacea. He recorded the surprising occurrence of the Arctic Isopod *Aega ventrosa* and several other N. Atlantic forms such as *Sympleustes grandimanus*, *Thoriella islandica* and *Koroga megalops* in the Arabian sea at great depths. In regard to the Indian barnacles there has been no substantial increase in our knowledge since Annandale (1914) published his studies on the genera *Scalpellum*, *Lithotrya*, *Oxynaspis*, *Alepas*, and *Heterolepas*, representatives of which were recorded from the Burmese and the Baluchistan coasts. The same author (1924) contributed a study of the Cirripedes associated with the Indian corals of the families Astraeidæ and Fungidæ. Sewell (1926) published an interesting and valuable paper on the variation in the external characters of the various so-called species of *Lithotrya* and showed that the species were only stages in the growth of, or varieties and life-phases of a single species, *e.g.* *L. nicobarica*. Monod (1934) gave an account of the comparatively little known copepod *Panaietis incamerata* Stebbing which is of common occurrence as a parasite in the buccal cavity of *Trochus niloticus* in the Andamans, but the most striking and single largest contribution on any group of the lower Crustacea was by Sewell (1929–1932) who gave a detailed account of the surface-living and mid-water Copepods of the Indian seas. He was of the opinion that much of the apparent difference between surface and littoral Copepod fauna of the Indian and Atlantic oceans was due to lack of knowledge, and such differences as exist were to be attributed to the presence in the latter of indigenous forms evolved in that area and to the total absence of connecting passages between the tropical or temperate regions of the Atlantic, the Pacific and the Indian oceans. He attempted to trace the mathematical relationships between the various growth stages not yet proved by actual breeding. He also drew attention to the fact that two sexually mature groups within the limits of the same morphological species occur commonly in the Calanoida and Harpacticoida in Indian waters particularly in the coastal

and littoral regions around the mouths of the great rivers, and living in the same locality and under the same conditions of salinity and temperature. The difference between the two groups is only in size, and differences in structure such as exist are so slight as to be of no value for purposes of separation into distinct species. Sewell was of opinion that dimorphism occurs in various species in both sexes. In regard to growth he showed that the Copepoda follow Brooke's Law by which growth increases at each moult by a fixed percentage of its length which is constant for the sex and the species, subject only to variation in growth-factor due to the influence of the environment.

Mollusca.—In regard to this phylum the period under review was one of considerable advances in our knowledge of the fresh-water forms, nevertheless some notable contributions have been made on the marine and brackishwater mollusc fauna. The Cephalopods of the deep-waters collected by the 'Investigator' in the Bay of Bengal and the Arabian sea were reported on by Massy (1916) and included such interesting forms as *Bathyteutis abyssicola* Hoyle from a depth of 2,000 fathoms and *Sepia arabica* Massy from the Laccadive sea and the Persian Gulf. Robson (1929) contributed a valuable monograph on the Octopoda dealing with several species from the Indian seas including Ceylon, Laccadives, Maldives, Andamans, Mergui and other coasts of Burma. The molluscs of the Chilka Lake and the backwaters and estuaries along the Indian coasts were described in a large series of papers by Preston (1914-15). Annandale and Kemp (1916–1923), and Prashad (1927). Hornell (1916-1917) published a revision of the Indian *Meretrix* and discussed the position of the Indian varieties and races of the conchshell of the genus *Turbinella* (now *Xanchus*) which are divided into 2 forms—the ancient *acuta* form including the vars. *fusus*, *globosa*, and *comorinensis* and the typical *obtusa* which is a divergent and changed form. The var. *fusus* attained specific rank by isolation from the *acuta* form. The distribution of these varieties is peculiar. The var. *obtusa* is found in Palk Bay and on the coasts of India only north of Adam's Bridge, while *acuta* is distributed along the coasts of the Gulf of Manaar. The vars. *globosa* and *comorinensis* are confined to the deep and shallow waters respectively of the extreme south of the Indian peninsula. Vredenburg (1917) gave an account of the peculiar variations of the aperture of *Pleurotoma congener* from the Andaman sea at a depth of 185 fathoms, and of the peculiarities of distribution of the members of the family Doliidæ. He (1919) showed also that *Dolium* (now *Tonna*) *maculatum* (Deshayes) and *D.* (*Eudolium*) *tessellatum* Bruguiere were distinct species, although the latter may be regarded as *Eudolium* when immature and *Dolium* s. str. when full-grown. *D. tessellatum* does not extend further west than the Eastern portions of the Bay of Bengal while *D. maculatum* does not extend further east than the Malay islands but is widespread in the Arabian

sea. Prashad (1927) described the new deep-water *Pyrulasewelli* from the Laccadive sea (180 fms.) with a distinctive minute sculpture. Winckworth (1928-1929) contributed several articles on the marine molluscs of S. India and Ceylon, chiefly the Chitons and Limpets. He (1933) described *Acanthochitona penetrans* from holes bored by bivalves on the shell of live *Trochus niloticus* in the Andamans, a form that bridges the gap between *Acanthochitona* and the Cryptoplacinæ. The Indian Oysters were the subjects of detailed study during the last quarter of a century. Moses, and Awati and Rai, published accounts of the life-history and anatomy of the common edible backwater Oyster, *Ostrea virginiana* (*O. arakanensis* Sowerby according to Winckworth) var. *madrasensis* and the Bombay Oyster, *Ostrea cucullata* respectively. Prashad and Bhaduri (1933) discussed the systematics of the Indian pearl oysters of the genus *Pinctada*, while Rao (1936) studied the morphology of the Indian nudibranch, *Kalinga ornata*. The growth of molluscs of the Indian seas was latterly the subject of study by Sewell (1924) and by Rao (1936). The former gave an account of his observations on growth in *Littorina*, *Pyrazus* and other forms of marine molluscs, while the latter dealt with in some detail the rate of growth, longevity, and habits of *Trochus niloticus*, the shell of which is a product of commerce in the Andaman islands. Some of the molluscs doing damage to the shell of *Trochus niloticus* were described by Prashad and Rao (1933), and Winckworth (1928-29, 1933).

Tunicata and Cephalochordata.—Oka (1915) described a number of interesting Ascidians from the deep-waters of Indian seas. Among those were the rare large Appendicularian *Megalocercus* Chun previously known only from the Mediterranean, and the simple Ascidian *Hexacrobylus indicus* from a depth of 1912 fathoms. The only known previous record of this latter aberrant genus was *H. psammodes* collected by the Siboga Expedition. Oka showed clearly that the division of the Ascidians into simple and compound forms was highly artificial. The curious genus of simple Ascidian, *Monobotryllus* Oka, has for instance its nearest relations among the holostomatous compound Ascidians and forms a link between the Styelidæ and the Polystyelidæ. Oka also recorded for the first time the occurrence in the branchial sacs of two widely different species (*Polycarpa annandalei* and *Ascidia willeyi*) of commensal macrurans. The Indian Monascidian, *Herdmania* (*Rhabdocynthia*) *pallida* was the subject of a monograph by Das (1936). The Salps of the Bay of Bengal and the Arabian sea were dealt with in detail by Sewell (1926). Prashad (1934) gave an account of the Cephalochordates of the genera *Branchiostoma* and *Asymmetron* from the Indian coasts along the Bay of Bengal and Gulf of Manaar and described the new species, *B. gravelyi*, closely allied to *B. elongatum* from the coast of Tuticorin but differing from it in the myotome formula, the form of the fins, and in the

absence of eyes. Franz (1925) proposed an exhaustive systematic revision of the Cephalochordate genera *Branchiostoma* and *Asymmetron*.

Vertebrata (*Pisces*).—The only comprehensive studies undertaken in the period under review were those of the littoral and deep-water flat fishes by Norman (1928) and of the fishes of the Chilka Lake by Chaudhuri (1916–1923) and Hora (1923). The Indian Torpedinid fishes received some attention at the hands of Prashad (1920). A monograph on the common Indian Shark, *Scoliodon*, by Thillayampalam (1928), and a detailed study of the skeletal morphology of *Otolithus ruber* by Dharmarajan (1936) formed important contributions to the study of Indian fishes. The papers of Fowler (1933–37) on the littoral and shore-fish fauna of W. India, Bombay coast and Ceylon, of Hora (1924) on certain interesting forms of fish of the genera *Amblyotrypauchen* and *Kanduka* from the Sandheads at the mouth of the river Hughli, and of Hora and Mukerjee (1936) on the Indian Syngnathids from the Andamans and Mergui and on the fishes of the Tavoy coast of Burma were valuable additions to the faunistic studies of the Indian littoral fishes.

In regard to other classes of marine Vertebrates there have been no substantial additions to our knowledge. The occurrence of *Gavialis gangeticus* in the Chilka Lake, and of *Crocodilus porosus* several miles out at sea at one end and up to the tidal limits of the larger rivers at the other has been recorded by Malcolm Smith (1931). The egg-laying and other habits of the Ceylon marine turtles, *Dermochelys coriacea*, *Eretmochelys imbricata*, *Chelonia mydas* and *Caretta caretta olivacea* have been elucidated by Deraniyagala (1930), while the skeletal characters of *Balaenoptera edeni* Anderson from the Burmese coast near the Gulf of Martaban were described by Andrews (1918).

V. Helminthology.

The study of Helminthology in this country may be said to date from 1869 with the publication of Cobbold's reports on the helminthic parasites of horses, elephants, and dolphins. Giles (1892) described helminths from sheep and mules while Linstow (1904–06) reported upon helminth collections from the Colombo Museum. All these materials were, however, collected in India for European specialists, but the first work done in India was by Evans (1908–10) who reported upon the helminthic diseases of elephants from Burma. Later, Mitra and Ganguly (1915) studied in India canine filariasis and *Gnathostoma* in Cats. Leese (1911) reported on the tapeworms of camels and on the occurrence of Bilharziosis in these animals, while Gough (1911) discovered a sub-family of Cestodes without yolk glands. Lane's observations on Ancylostomiasis in certain parts of India and on the suckered round-worms,

and his descriptions of new genera and species of round-worms from Indian elephants are of great value. Stewart (1914) in his studies on Indian Helminthology described a number of Nematodes. Gaiger's (1910–15) check lists of the animal parasites of domesticated animals are useful contributions to the study of Indian Helminthology. These studies, although mainly of a morphological nature include observations on the larval stages of the parasites as in the papers of Stewart (1914) on Indian nematodes etc., and of Dey (1909) on a case of *Coenurus* infection in the goat.

The great European war marked the beginning of a new era of helminthological research in India. Leiper, as head of the Bilharzia Mission, drew the attention of the Government of India to the cases of Schistosoma infection among Indian troops returning from Egypt and Mesopotamia and stationed in Hyderabad (Deccan), and to the possible spread of the infection to other parts of India. A few cases of Schistosoma infection in 1924 in Chinese coolies working in the Bawdwin silver mines in Burma also directed attention to the possible spread of Schistosomiasis from the Far East into Burma. Kemp and Gravely (1920) examined a large number of larval Trematodes from various species of freshwater Gastropods in selected localities in India, but found furcocercous larvæ of the Distome group as a natural infection only in two species of Gastropods, and these larvæ did not in any of their features agree with those found in cases of human Schistosomiasis. Infection experiments on Indian molluscs carried on with miracidia of human Schistomiasis gave negative results. Soparkar (1918–22) in the course of his studies in Bombay discovered cercariæ closely resembling those of human Schistosomes which were later proved to be those of the cattle Schistosome. The same author traced the life-history of a larval Trematode from the Anopheline mosquito to the fish-trematode *Clinostomum*. Sewell (1922) published a monograph on Indian Cercariæ, and suggested that Distomes were evolved from Monostomes, a view which as knowledge of the group advanced had to be abandoned. As a result of comprehensive studies of the excretory system in cercariæ he (1930) advanced the view that the furcocercous cercariæ were of polyphyletic origin, and the evolution of the Monostome by the suppression of the acetabulum has occurred on more than one occasion and in different lines of evolution. Bhalerao (1932) drew attention to the probable infection of man and domestic animals by species of *Isoparorchis*, and recorded the occurrence (1934) of *Schistosoma japonicum* in Indian pigs, which, if confirmed, would bring into prominence the question of the spread of the infection from pig to man through some suitable intermediate host. de Mello (1936) directed attention to a case of urinary Schistosomiasis in Portuguese India where ova of *S. hæmotobium* were found in the urine and faeces. Some local mollusc such as *Melanoides tuberculatus* or *Lymnaea luteola* is believed to have acted as the secondary or eventual intermediate

host and carried the infection. Eventual hosts in which miracidial attraction is often followed by penetration are held to be responsible for sporadic cases of Bilharziosis. The author has observed definite instances of miracidial attraction followed by penetration in regard to the species of molluscs mentioned above.

The growing appreciation in India of the value of helminthological studies is evident from the fact that they occupy an important place in the Imperial Veterinary Research Institute at Muktesar and in the Calcutta School of Tropical Medicine, and from the fact that considerable research on the taxonomy and morphology of helminths is being conducted under the auspices of Universities in India. Among the Universities pursuing studies in Helminthology may be mentioned Rangoon, Lucknow, Aligarh, Allahabad, and Nagpur. The results of these studies have been published in well-recognized scientific journals and periodicals both in India and abroad.

In the present article only passing references are made to the veterinary and medical aspects of helminthological studies as these are dealt with more fully and appropriately in the sections on Veterinary and Medical Sciences respectively of this work.

Trematoda.—By far the largest volume of work has been published on this group. The Dicrocoelid parasites from domestic animals have been reported on by Ware (1923). These have been recently supplemented by the studies of Bhalerao (1936-37) on this and other families of Trematodes. The families Lepodermatidæ, Spirorchidæ, and Lecithodendriidæ, and the sub-family Pleurogenetinæ have received considerable attention at the hands of Mehra and his colleagues (1931–1935). They have suggested revised classifications of some of these groups and indicated the probable phylogenetic relationships. Verma (1930) has studied the genus *Opisthorchis* and several new parasites of the family Bucephalidæ found in water-birds. The Trematode parasites of fishes and frogs and the systematic position of some of the new forms described have been dealt with in a series of memoirs by Srivastava (1933–1936). The seasonal variation and maximum frequency of infection of several of these parasites have also been studied by the same author (1934). The Indian Echinostomatid genera, *Echinochasmus* and *Episthochasmus* have been fully described by Verma (1935). The digenetic Trematodes of the genera *Lecithodendrium* and *Mesodendrium* parasitic in Microchiroptera have been dealt with by Pande (1935). The genus *Cyclocoelum* was recorded for the first time in India by Khan (1935) who described several new forms and provided a key to the Indian species. Moghe (1932) and his colleagues at Nagpur have recorded the occurrence of some interesting forms of *Echinostomum* and *Paramonostomum* from Indian birds.

The Lucknow School of Helminthology under the direction of Thapar has greatly assisted in the systematic identification of

helminth parasites of various animals. Thapar[1] has recently summarized the results achieved by this school in a small brochure entitled '*Parasitic Worms and Disease*' published under the auspices of the Lucknow University. The relationships of the sub-families, Spirorchinæ and Hapalotreminæ, and of the families Allocreadiidæ and Heterophyidæ, the probable course of evolution of the family Psilostomidæ from Allocreadiidæ, and the polyphyletic origin of Echinostomes have been discussed by Thapar, Dayal and Lal in a series of papers (1933–1936). The value of different characters in the classification of Trematodes have been recently discussed by Lal (1937). Vidyarthi (1937) and Lal (1934–1937) have made valuable contributions on the Trematode parasites of Indian birds. Harshey (1937) has given a key to the genera of Opecoelinæ and to the species of *Opegaster*. Pande (1937) has discussed the systematic position of the new bladder fluke, *Phyllodistomum almorii*, from *Rana cyanophlyctis*. In Madras the Trematodes of domestic animals have been studied by Rao, who described new species of Cercariæ and reported on bovine nasal, and canine Schistosomiasis in Madras (1933), and recorded the occurrence of *Paragonimus* in dogs in certain parts of Malabar and Coimbatore (1935). Fernando (1932) has recorded his observations on *Mesocoelium* and *Haplorchis* from Ceylon.

Cestoda.—The Cestode parasites of birds and fishes have been studied by Southwell since 1911, who, in addition to publishing a series of interesting memoirs on the subject, has contributed two volumes on the Cestodes in the *Fauna of British India* series (1930). Meggitt's careful studies of the taxonomy and life-history of Indian Cestodes have materially advanced our knowledge of the group. The Helminthological Institute of the University of Rangoon owes much to his efforts. The Host-specificity theory of Meggitt (1934) was shown by him to be inapplicable in the case of the Cestodes. Recent work by other investigators in India supports his views in certain other groups of helminths as well. The tapeworms of dogs in the Punjab were studied by Sondhi (1923), while Aggarwala (1925) reported an unusual location for *Echinococcus* cysts in the body of the sheep. A new *Monopylidium* and certain other new Cestodes were described by Moghe (1925–1933) from Indian birds and reptiles, while Gulati (1929) gave an account of a new *Dipylidium*. Johri (1931–1935) and Inamdar (1933-1934) are among others who have made important contributions on the Cestode parasites of Indian birds. Woodland (1923–1926) considered the Caryophyllæidæ as a primitive group of Cestodes, which was contrary to the views of Lonnberg and others who regarded them as secondarily monozootic, and showed that their affinities were with the Gyrocotylidæ. Verma (1926, 1928) de-

[1] Thapar, G. S.—*Parasitic Worms and Disease*: Lucknow University Series, No. 3, 1936.

scribed several new forms of the order Tetraphyllidæ and the family Proteocephalidæ. Thapar recently discovered the interesting fact that *Echinococcus* cysts simulate those of *Coenurus*. Malkani (1933) has investigated the problem of evagination of the scolices of larval tapeworms and found experimental evidence for the fact that the process of evagination is helped by surface tension. Bhalerao (1936) reviewed the known species of *Avitellina* and furnished a key.

Nematoda.—Much work on parasitic Nematodes has been done by pathologists in India among whom may be mentioned Lane, Stewart, Chandler, Maplestone and others. Our knowledge of Ancylostomiasis, Ascariasis, and Filariasis are due, in great part, to their efforts. The Rockfeller Foundation of America has also sponsored research work along these lines. Sheather (1919 and 1920), Boulenger (1920–1924), Ware (1924) and Chandler recorded their observations on several forms of Nematodes from cattle, elephants, and other animals. Thapar (1924-1925) described several new species of *Kiluluma*; he discussed the relation between the spicules and vagina in *Oesophagostomum* and modified Goodey's formula with a view to make it generally applicable to all members of the group, and to make it useful in distinguishing various species. In an important paper, Thapar (1925) has added considerably to our knowledge of the taxonomy of Nematodes. He demonstrated the presence of spines resembling rose-thorns in form in the oesophagus, and of intestinal diverticula in *Echinopharynx*. In the latter feature the genus resembles certain members of the family Ascaridæ. In the Oxyurids parasitic in reptiles the same author demonstrated the presence of cilia guarding the excretory pore of certain forms, and showed that the group, far from being primitive as was believed by Seurat and others, is a highly specialized one and has attained simplicity through degeneration. He also pointed out that the difference between *Tachygonetria* and *Thelandros* lies mainly in the character of the genital papillæ, and established the new family, Labiduridæ. The Nematode parasites of various species of Vertebrate animals have been studied by a number of workers in India. The publication of a volume in the *Fauna of British India* series on the Ascaroid and Strongyloid Nematodes by Baylis (1936) has served to bring together the scattered literature on the subject, a reference to which will be found to be indispensable by every student of Indian Nematoda. Barsikar (1926) reported on the occurrence of guinea-worm in domestic animals from certain parts of the Bombay Presidency. Mirza and his associates (1930–1936) have described a number of new Nematodes from Indian Vertebrate hosts. Among these, *Diserratosomus* Mirza (1933) from the mongoose is of interest in that it is claimed by its author to be a connecting link between Nematodes and Acanthocephala. Maplestone (1930-1931) and Bhalerao (1932–1935) added considerably to our knowledge of the Nematodes of

the domestic animals, while the former recorded several species occurring in wild animals acclimatized to the conditions of the Calcutta Zoo. Kulkarni (1935) recorded a second species of *Procamallanus* from India from a Siluroid fish, while Pande (1935) recorded *Pycnoporus* for the first time in India and provided a key to the species known. Patwardhan (1935) described a new Oxyurid, *Latibuccana* from the squirrel. Since Carter published his observations on *Dracunculus* of Bombay very little work has been done on this genus in India, but Mirza (1929) has cleared certain points in regard to the anatomy of *Dracunculus*. Iyengar (1929) gave an account of the Nematodes parasitic in the Anopheline mosquitoes of Bengal and Karve (1930) those in frogs and toads. Rao and Iyengar (1932) have demonstrated the interesting process of emergence of *Filaria* larvæ through the extreme tip of the labella of *Culex fatigans* without any stimulus from mechanical pressure or from heat. The Nematodes parasitic in plants seem to have received very little attention in this country. Butler (1919) dealt with the rice-worm *Tylenchus angustus*, and more recently Dastur gave an account of the nematode disease of rice due to *Aphelenchoides*. Free-living Nematodes seem to have attracted still less attention. Excepting Carter's incomplete accounts (1855–1859) of the free-living forms in brackish- and freshwater areas of Bombay, and Stewart's (1914) report on the free-living Nematodes of Chilka Lake there are no references to this subject in Indian zoological literature.

Acanthocephala.—The short summary of Indian literature given here on this interesting group of parasitic worms indicates the wide scope for work in this country, and the necessity for evolving a natural system of classification for the group. Thapar (1927) suggested a tentative classification which, according to him, would admit of the inclusion of a large number of known forms. His classification was adopted in part by van Cleave (1928) who, in reporting on the Indian Acanthocephala, erected the families Pallisentidæ and Hebesomidæ unaware of Thapar's work. Verma (1929), Subramanian (1927), Thapar (1930), Bhalerao (1931) and Datta (1928–1936) described a number of new forms from India and Burma, and brought forward evidence to show that some of the characters on which Thapar based his classification of Acanthocephala are sound. More recent work on this group in Western countries also lends support to their view.

In a recent review of the study of Helminthology in India Thapar (1937) has suggested the application of accurate nomenclature and the selection of suitable types of helminths for study in our Universities and colleges teaching Zoology. In this work the author has also given some of the references to Helminthology in ancient Indian literature.

The investigations now in progress at Lucknow on the helminthic infections of domesticated animals in India under the auspices

of the Imperial Council of Agricultural Research are looked forward to with interest as the results would be of value to the whole of agricultural India.

VI. Conchology.

The foundations of the study of Indian Conchology were laid in the latter half of the nineteenth century by a host of European workers in India among whom may be mentioned Hutton, Benson, the Blanford brothers, Stoliczka, Theobald, Beddome, Godwin-Austen, the Nevill brothers, and Smith. With the retirement of most of these notabilities from service in India the study of Conchology so well started by this band of pioneer workers came practically to a standstill. But the work of Blanford (W.T.) and Godwin-Austen on Indian Mollusca continued, resulting in the publication of the first volume of land molluscs in the *Fauna of British India* series (1908). A separate periodical publication entitled *Land and Freshwater Mollusca of India* by Godwin-Austen which was issued as a supplement to the well-known *Conchologia Indica* by Hanley and Theobald (1870–1876) was discontinued in 1920.

The revival of intensive work on Indian Conchology came about in 1910 when Annandale caused the collections in the Indian Museum from different parts of India to be studied by Preston, Fleure, Gude, Godwin-Austen, Kobelt, Ghosh and others. Preston's studies of Asiatic Unionidæ (1912) were followed by the *Fauna* volume (1915) on Freshwater Gastropoda and Pelecypoda of India. Two more volumes in the *Fauna* series by Gude appeared in 1914 and 1921. It may be mentioned here that all the work connected with these volumes was done outside India, but a few faunistic reports by Annandale, Kemp and Prashad on molluscs from estuarine waters in the Gangetic Delta, the Cochin Backwater, and the Chilka Lake were, however, published in this country.

The study of Mollusca in India from the conchological and malacological points of view was, however, commenced for the first time in India by Annandale (1918) who studied the molluscs of the Inlé Lake in Burma from various points of view. The relation of the individuals of the species of molluscs to their environment, the inherent plasticity of certain species found living there, and the probable origin of the molluscan fauna in that specialized lake were some of the points discussed by him. About the same time a survey of the Indian freshwater Mollusca with a view to investigate the possibility of their acting as vectors of human schistosomiasis was undertaken. The materials that were collected in the course of the survey formed the subject of a series of reports on various families of molluscs by Annandale, Prashad, Sewell, and Rao. As a result of these studies our knowledge of the systematics, distribution and mutual relationships of the freshwater molluscs of India is probably as detailed as that of any other part of the world. Among the contributions of value on the taxonomy

and morphology of Indian Gastropoda as a result of these intensive investigations are those of Germain (1921–1924) on the Planorbidæ, of Annandale (1918–1924), Sewell (1921), Prashad (1928) and Rao (1925, 1928, 1929) on the Viviparidæ, of Prashad (1925) on the Ampullariidæ, of Rao (1923, 1924, 1925) on the Planorbidæ, Succineidæ, and Lymnæidæ, and of Seshaiya (1932) on the Melaniidæ. The structure of the mantle which is concerned in the production of a highly varied ornamentation on the surface of the shell in certain members of the Viviparidæ was investigated in great detail by Annandale (1921, 1924) and Prashad (1928).

The morphology and taxonomy of freshwater Pelecypoda were investigated chiefly by Ortmann, Prashad, Ghosh, and Haas. The details of the morphological work will be referred to in the section on Morphology, and it is only necessary to point out that the contributions of the first two authors are of importance in evaluating the relationships of the Indian genera.

Although a reference to the Mollusca of the extra-Indian regions such as China, Japan, and the Dutch East Indies would be out of place here, the close relationships of certain groups of Indian Mollusca to those of the areas mentioned render it desirable to make a passing mention of the work done in India on extra-territorial material. Annandale's papers on Chinese and Japanese freshwater Molluscs, and Prashad's contributions on the Mollusca of the Dutch East Indies are of this nature.

VII. Carcinology.

The progress of marine and brackishwater Carcinology during the last 25 years has already been referred to in the section on Marine Zoology of this account. It now only remains to point out the lines on which research on freshwater and terrestrial Crustacea has progressed.

Greater attention seems to have been paid to the Entomostraca, Isopoda and Amphipoda, while the Decapoda received scant attention. Southwell (1915) and Southwell and Prashad (1918) described the Copepod and Isopod parasites of freshwater fish. Gurney (1919–21, 1930) wrote short papers on the Branchiopoda, and enumerated the species of Entomostraca occurring in Seistan and the Baluch-Desert. Bär (1925) described the Cladocera of Ceylon. Kieffer (1923) and Lindberg (1935) published some notes on the Copepoda Cyclopidæ, and Chappuis (1928) on the Harpacticidæ. Raj (1923) described a new copepod parasite of a freshwater fish and Steuer (1934) two new copepods from Burma. The Ostracoda have received very little attention, and the only contribution to our knowledge of this group has been that of Klie (1927).

Collinge (1914–1916) described the Isopoda of the Abor country in Assam and established several new genera and species from other

parts of India also. Tattersall (1921) dealt with the Isopods of the Tale Sap and other Asiatic lakes, in the series of papers entitled 'Zoological Results of a Tour to the Far East'. Chopra (1930) gave an account of the Bopyrid Isopods that are almost or entirely freshwater, and of the terrestrial Isopods of the Siju cave in Assam. The interesting myrmecophilous Isopods of Barkuda Island in the Chilka Lake were described by the same author (1924). Verhoeff (1936) has published an account of several South Indian terrestrial Isopods.

A considerable amount of work has been done on the Amphipoda also. Tattersall (1914) recorded the occurrence of the common and widely distributed *Gammarus pulex* at a height of 15,600 feet above sea level in the Pamirs. He was also the author of a number of papers on the Abor Amphipoda (1921), the Far East Amphipoda (1922) and some freshwater Amphipods from the Andaman Islands (1925). Chilton (1923) described the blind Amphipod, *Niphargus indicus*, from a coal mine in Bengal, while eight years later Stephensen recorded this very form from a seepage spring under the generic name, *Neoniphargus*.

Kemp's contribution to our knowledge of the Decapoda is the most outstanding. In a large number of his papers (1917–1924) that deal mainly with marine and estuarine forms, a number of species that are at least partially freshwater have also been included. He gave an elaborate account of *Leander styliferus* and its related forms, several of these being almost exclusively freshwater. A partial revision of the Atyidæ, a family that is restricted more or less exclusively to freshwaters, was suggested by him. He also revised the Hymenosomatidæ, some of the forms dealt with being found in freshwaters also. In 1918 he gave an account of the Decapoda of the Inlê Basin in Burma, while in 1919 he revised the crabs of the subfamily Scopimerinæ. Most of these crabs are estuarine, but a number of species invade waters that are, almost or quite, fresh. In 1924 he described a new *Palæmon* with considerably reduced eyes from the Siju cave in Assam. Roux (1931) gave an account of some freshwater Decapods from Mysore and the adjoining parts, and also described a new *Caridina* from Ceylon. Chopra and Das (1930, 1935) published notes on Hymenosomatid and Potamonid crabs occurring in freshwaters of various parts of India.

VIII. Entomology.

With a great variety of climatic and physiographical features, of forests, and of cultivated crops in India it is to be expected that the Insect fauna will be extremely rich and varied. The progress of our knowledge of the Insects was at first slow, only a thousand species being known from India up to the end of the 18th century. But the monographs of Niceville, Atkinson, Wood-Mason, Swinhoe,

Dudgeon, Hampson, Green and others on various groups of Insects published during the last quarter of the century bear evidence to the fact that the Insect fauna of India attracted considerable attention amongst European workers stationed in this country.

The recognition of the value of Entomology to India by the Government resulted in the appointment of Entomologists to the various scientific institutions in this country such as the Indian Museum, the Imperial Agricultural Research Institute, the Forest Research Institute, and the Provincial agricultural and medical research institutes. The volume of work done by these institutions within the last fifty years can be judged from the innumerable catalogues and other works on various groups of Insects that have been published from time to time. In addition, detailed systematic work has led to the publication of monographs or a series of papers such as those by Fletcher on the Microlepidoptera, by Beeson on the beetles of the families Scolytidæ, Platypodidæ and Cerambycidæ, by Sinton on the Sand-flies (*Phlebotomus*), by Awati, Patton and Senior-White on Muscoid flies, and by Puri on the Simulidæ.

With the inauguration of the *Fauna of British India* series under the authority of the Secretary of State for India the need for a consolidation of our knowledge of the Insects of this country had been met, and by about the last decade of the 19th century some of the volumes on the Insecta (Lepidoptera, Coleoptera, and Rhychota) in the *Fauna* series had begun to appear. If the number of volumes published be taken as a measure of the progress in Entomology, it will be seen that up to 1914 a score of volumes dealing with moths and butterflies (Lepidoptera), bees, wasps and ants (Hymenoptera), bugs (Rhychota) and beetles (Coleoptera) had been published, whereas within the last quarter of a century twenty-three volumes have been added to the series. Of these, twelve have been devoted to the single order Coleoptera by Marshall, Arrow, Andrewes, Cameron, and Maulik, one volume each to the Acridiid Orthoptera and the Sphingid Moths by Kirby and by Bell and Scott respectively, two volumes to the Rhynchota (Homoptera) by Distant, two volumes to the Diptera (Brachycera) and several other families of Diptera by Brunetti, two volumes to the Anopheline and Culicine mosquitoes by Christophers and Barraud respectively, and three volumes to the Odonata by Fraser. Several other volumes now under preparation are expected to be published shortly. Nearly all the groups of Insects dealt with in these volumes are of great economic importance. A majority of the bugs, beetles and locusts, are concerned in the destruction of cultivated plants, the blood-sucking Diptera are mostly transmitters of disease (Malaria, Dengue, Filaria, Plague, etc.) to human beings and their domestic animals, some Coprine and Staphylinid beetles act as scavengers, while other Insects such as the Carabid beetles and the dragon-flies play a beneficent rôle in controlling the numbers of Insects injurious to man. These later volumes on Insecta in the *Fauna*

series, although mainly systematic in intention include a great wealth of information on the general morphology, bionomics, and distribution of the groups of Insects with which they deal. Much of the information published in India or abroad is no doubt incorporated in these volumes, but there is a great deal, relating to groups of Insects already dealt with in the older volumes or to those which form the subject matter of future volumes, which has been published in Zoological journals in India and elsewhere.

A considerable proportion of this published literature relates to the groups, Diptera, Coleoptera, Hymenoptera, Rhynchota and Odonata. The other groups such as the Thysanoptera, Orthoptera, Neuroptera, and Ephemeroptera have received relatively scant attention. A summary of the work done on each of these groups would occupy more space than is available, and for the purpose of this review it is considered adequate to indicate briefly the trend of research which is often conveyed by the title of individual articles.

Diptera.—By far the largest number of papers dealing with this group of Insects seems to have been published during the period under review. Brunetti (1914) reviewed the Culicid genera and discussed the value of characters used in classification and (1915, 1918) gave an account of the Oriental Tipulidæ and Syrphidæ. The *Fauna* volume by this author dealing with the Diptera Brachycera was published in 1920. The same author made a revision of the Oriental Stratiomyidæ (1923) and of the Indian Syrphidæ, Conopidæ and Oestridæ (1925). Alexander (1927) published his studies of the Oriental Tipulidæ and Polymitarcidæ while Edwards (1932) gave an account of the Ceratopogonid and Chironomid flies of Barkuda I. in the Chilka Lake. Christophers (1933) dealt with the Anophelines and Barraud (1934) with the Culicines and the non-blood-sucking Megarhine Diptera in two volumes of the *Fauna* series. A number of papers on Flies (Muscidæ) appeared during the last twenty-five years. Townsend (1917) described the Rhiniinæ giving a key to the genera included in that sub-family. Patton and Senior-White (1924) dealt with the Oriental species of *Musca*, while the latter author (1924, 1925, 1926, 1930) in a series of papers revised the Muscoid flies belonging to the sub-families Sarcophaginæ, Rhiniinæ, and Calliphorinæ and gave exhaustive distributional records. The Blepharoceridæ and Psychodidæ of the Indian Region have been studied by Tonnoir both from the systematic and the biological points of view. He (1930, 1932) gave an account of the morphology and metamorphosis of the Indian Blepharocerid larvæ and pupæ, and revised (1931) the type-material of *Blepharocera indica* and *Philorus bionis* discussing the generic status of the latter. The study of the curious Indian Psychodid genera *Horaiella* and *Telmatoscopus* gave him the scope to discuss the origin and evolution of the suckers developed in the larvæ of these genera and also in those of the Blepharoceridæ (1933). He believed that the evolution of the sucker was gradual

from the fact that in the first stage the dorso-ventral flattening of the body gave a large surface of adhesion, in the next stage a sucker-action was brought about on the entire ventral surface by the dorso-ventral muscles, accompanied by the development of a pleural fringe of hairs to facilitate the retention of the vacuum, in the third stage this fringe migrated towards the axis of the body to allow mobility and developed into a series of continuous or interrupted oval discs, which evolved in the final stage into powerful types of suckers. This view was refuted by Hora (1933) who thought that the evolution of these forms was from different ancestors and that the superficial resemblance between them is due to convergence in response to similar habitats. A more detailed study of morphological adaptations of Insect larvæ (including various Dipterous and other forms) to life in torrential waters was made by Hora (1930). The Indian Simuliidæ were studied by Puri (1932) from the systematic point of view. The Indian Asiliid Diptera were comparatively little known, and Bromley's (1935) study of this group is therefore an important contribution. Since Bezzi's monograph of the Trypaneids (Fruit-flies) very few records have been published in India, and the recent account of these flies by Munro (1935) is therefore of value. The Itonidid gall-producing midges have been very little studied and the series of contributions on this group of Insects by Mani (1934, 1935, 1936, 1937) fill up a considerable gap in our knowledge. The Diptera which inhabit the sea-coasts seem to have attracted very little attention, and a note on the life-history and habits of the Metopiid shore-fly, *Sarcophila cinerea*, by Venkatraman (1936) is a useful addition to our knowledge of this group. The Diptera Pupipara of the family Nycteribiidæ which are usually parasitic on bats are a little known group of Insects, and Scott's (1925) studies on the zoogeography and systematics of this group are of considerable interest.

Coleoptera.—A more or less complete review of our knowledge of Indian beetles of the families, Chrysomelidæ, Curculionidæ, Scarabæidæ and Carabidæ, and of the Clavicornia is to be found in the volumes of the *Fauna* series relating to this group of Insects. The reader is referred to these volumes for further information. The progress of our knowledge of such of the families of beetles as have not been dealt with in these volumes will be summarized in this paragraph. Gravely (1915, 1916) has contributed valuable studies on the stages in the life-histories of various beetles from India and Burma. These deal with the larvæ, pupæ and adults of the Tenebrionidæ, Cucujidæ and Lycidæ. The determination of genera from the characters of the larvæ has been discussed. The same author (1915) has studied the Lucanid beetles, giving a key to some genera, and published (1918) a revision of the Passalidæ of the World which is a land-mark in the study of Coleoptera in this country. Short contributions on various families of beetles have been made, by Paiva (1919) on the bionomics of the

Indian glow-worm, *Lamprophorus tenebrosus*, by Emden (1926) on the Sandalid beetles, by Ochs (1925, 1929) on the Gyrinid beetles of the plains and of high altitudes, by Ribiero (1930) on the Paussid beetles using the male genitalia for the first time as the criterion for classification, by Khatib (1934) on the biology and life-history of the Chrysomelid, *Galerucella birmanica*, and by Paulian (1936) on the South Indian and Ceylonese Aphodiine Lamellicornia. The publication of two volumes by Beeson in the *Fauna* series on the Platypodid and Scolytid beetles is looked forward to with interest.

Hymenoptera.—This is the next order of Insects which has received considerable attention in India. One of the earlier papers in the period under review is that by Rohwer (1915) on the little known Siricoid and Tenthredinoid saw-flies, but more recently Malaise (1934) described the Himalayan forms of the latter group. The equally little known Bethylid Hymenoptera were studied by Muesebeck (1934) who studied material collected in South India. The most valuable contribution to our knowledge of the Hymenoptera relates to the interesting group of parasitic forms known as the Chalcidoidea. Ayyar (1934) recorded the Chalcid genus *Comperiella* for the first time in India and described a new species parasitic on the scale insect, *Aspidiotus tamarindi*, while Mani (1935, 1936, 1937) has contributed a series of interesting papers on the parasitic Chalcidoid families Torymidæ, Cynipidæ, Scelionidæ and Chalcididæ. Among these are included the Encyrtid *Solindenia* parasitic in the oothecæ of a Blattid cockroach, and the new Encyrtid, *Krishnieriella*, parasitic on the pulse scale-insect, *Ceroplastodes cajani*.

Among the short papers may be mentioned one by Sen (1931) which gives an account of the males and females of certain Pompilidæ, Sphegidæ and Apidæ, and several others on the habits of wasps, bees, and ants published mostly in the volumes of the *Journal of the Bombay Natural History Society*, and a paper by Dover (1922) which gives a short resume of the progress in our knowledge of the Indian wasps and bees. The recent classification of the ants (Formicidæ) by Emery necessitated a re-examination of the Indian species, and consequently the report of Mukerji (1930) on the Himalayan and South Indian ants with this classification as the basis is of value. Among life-histories of Hymenoptera which are of interest are those detailed by Mukherji and Bhuya (1936) on the Trichogrammid, *Chaetostricha mukerji* Mani, and by Ayyar (1937) on the carton-building ant, *Crematogaster dohrni artifex* Mayr.

Rhynchota (*Hemiptera*).—A large majority of these Insects live on the juices of plants, while a few live on the blood of animals. This group is therefore of great economic importance as being destructive to cultivated and other plants. The monograph on the Indian Aphididæ by Das (1918) and the studies on the Indian Coccidæ by Green (1919) are among the earliest contributions to our knowledge

of this group of Insects in the period under review. Krishnamurti (1928, 1930) described the Aphid fauna of Mysore while George (1925 and 1927) dealt with the S. Indian forms. Silvestri (1921) gave an account of the interesting termitophilous bug *Termitaphis annandalei* which was the first record of the occurrence of a Termitocorid in India. The young females and the adult males of this family were unknown to science until the Indian material was studied. Funkhouser (1922) described the Indian Membracidæ while Muir (1922) classified the Indian Derbidæ with the genitalia as the criterion. Distant (1916, 1918) contributed two volumes to the *Fauna* series dealing with nine families of Homoptera. Pruthi (1930, 1934, 1936) gave an account of the Indian Jassid Homoptera including several new genera and species, redescribing at the same time some of Distant's genotypes known only from very incomplete descriptions. Certain characters in the genitalia which are of sound classificatory value have been emphasized by this author. Hutchinson (1933) similarly found it necessary to revise the types of Notonectid and Corixid species described by Paiva and Distant. Very little is known of the Indian Aleyrodid bugs which are potential pests of some important crops, and transmit fungoid diseases. The account of these insects from Burma by Singh (1932) is of considerable interest in that 10 out of the 13 species recorded proved to be new.

Mathew (1935) contributed an interesting study of the transformational deceptive resemblance in the stages of life-history of the Coreid bug *Riptortus pedestris* to the red-ant *Oecophylla*.

Odonata.—The one outstanding contribution to this group of Insects during the last quarter of a century has been that of Fraser (1933, 1934, 1936) in the three volumes contributed to the *Fauna* series. The dragon-flies are of indirect benefit to mankind in keeping down the numbers of noxious flies, mosquitoes, moths, and other pests. A very interesting discovery of this period is the dragon-fly of the genus *Epiophlebia* which forms a connecting link between the two sub-orders of the Odonata, namely, the Zygoptera and the Anisoptera. The first species of the genus was described from a dragon-fly from Japan the larva of which was not known, while the second species described by Tillyard (1921) from the Darjeeling Himalayas is known only from its larva. Although repeated searches were made in the type-locality for the latter no further specimens have been obtained.

The Agrionid and Gomphine dragon-flies of the Indian Region were studied by Laidlaw (1919, 1922). The same author (1932) proposed a revision of the genus *Coeliccia* with special reference to the reproductive organs. The problems of evolution in the Order Odonata were discussed by Tillyard (1928) after analysing the basic characters of the related Protodonata and Odonata. A very useful aid to the student of Indian Odonata is the excellent key to the dragon-flies of the Sub-Order Anisoptera by Needham (1932).

To these must be added the numerous contributions of Fraser to the *Journ. Bombay Nat. Hist. Soc.* and other journals in India where he worked for several years. The detailed references to his works are given under the genera and species dealt with by him in the *Fauna* series.

Orthoptera.—This order is also of economic importance in as much as members of some families are notorious as destroyers of plant-life in general and of cereal crops in particular. Since the publication of Kirby's volume (1914) in the *Fauna* series dealing with the Acridiid Orthoptera several papers have appeared. Hancock (1915) described the Tetrigine Acridiids and gave a key to the genera of Tripetalocerinæ. Chopard (1921) gave an account of the cavernicolous Orthoptera from certain caves of Assam and other regions and revised the Indian Gryllidæ (1928). The Locust problem in India has attracted considerable attention in recent years owing to the serious damage done to crops both in N.-W. India and in the peninsular region, and the contributions of Rao (1933, 1935, 1936) towards the elucidation of this problem are of great value. The Indian Mantids or Praying Insects were studied by Werner (1935).

Thysanoptera.—This little known group of Insects the economic importance of which has only been realized in recent years seems to have few votaries in India. All the more credit, therefore, to Ayyar and Margabandhu (1928, 1931) who have contributed several papers on Indian Thysanoptera. Moulton (1929) studied the Indian Thripididæ and Phloeothripidæ, while Priesner (1933) revised the Indo-Malayan forms giving a key to the species of *Haplothrips*. The Indo-Malayan species of Japygidæ and Campodeidæ were studied by Silvestri (1930, 1933). The only contributions on the Collembola are short notes by Carpenter (1917) on the forms found in the Abor country and Lower Burma, and by Mukherji (1932) on certain forms common in Calcutta.

Ephemeroptera.—The Indian May-flies have likewise been neglected. Gravely (1920) published short notes on the Asiatic species of *Palingenia*, while Chopra (1927) published a more detailed account of the Indian Palingeniidæ and Polymitarcidæ belonging to the sub-Order Ephemeroidea. Recently Hafiz (1937) has dealt with all the four families of the sub-order Ephemeroidea including Ephemeridæ and Potamanthidæ.

Trichoptera.—The exhaustive account of the Indian Integripalpia and Annulipalpia by Martynov (1935, 1936) is an outstanding contribution to the study of this group of Insects. The latter group includes a large percentage of new forms. Moseley (1935) described the Phryganeid Trichoptera. Hafiz (1937) has given an account of the biology of the common Calcutta Caddis-fly, *Amphisyche indica*, with a description of the larval and pupal stages.

Neuroptera.—The only paper of importance on this neglected group of Insects is by Fraser (1922) who gave an account of the Oriental Ascalaphidæ (Myrmeleontidæ) with special reference to the larvæ.

Isoptera.—Among the papers of systematic importance on this group are those by Silvestri (1922, 1923) on the Indo-Malayan termites of the genus *Capritermes* and the termites of Barkuda I. in the Chilka Lake. An interesting account of the habits of the termites and of the structure of their nests has been given by Annandale (1923). A very useful contribution to our knowledge of Indian termites by Margabandhu (1935) is his annotated list of Indo-Ceylonese forms.

Lepidoptera.—Since the publication of the volumes in the *Fauna* series dealing with various families of moths and butterflies considerable literature has accumulated, of which the best part has appeared in the *Journ. Bombay Nat. Hist. Soc.* Bell and Scott (1937) have dealt with the Indian Hawk-moths (Sphingidæ) in the *Fauna* series. This work is exhaustive and contains considerable morphological details. The early stages of most species are described with coloured illustrations of the larvæ, pupæ, and imagines which help in the identification of the species. Keys to the genera and species of Sphingids based on all the three stages in their life-history facilitate the work of the student of this group. The larvæ of these moths are destructive to various families of plants. Puri (1931) has made a detailed survey of the butterflies of Lahore.

Anoplura.—At the beginning of the period under review, Kellogg and Paine (1914) described some lice from birds of the family Corvidæ and Phasianidæ, but the interest in this group seemed to lag until Qadri (1935, 1936) published his interesting series of papers on the Mallophaga of North Indian birds. His morphological papers are of value and are referred to in the section on Morphology.

Aphaniptera.—The study of this group has also been comparatively neglected. Sharif (1930) revised the fleas of the family Pulicidæ, while Iyengar (1935) furnished a key to the identification of the common genera of rat-fleas of India. Sharif (1937) studied the life-history and biology of the rat-flea, *Nosopsyllus fasciatus*, and showed that fleas require in addition to blood other food such as organic refuse, that fibrin of the blood is of no nutritional value, and that the supply of iron necessary for larval growth is all obtained from blood.

Although Entomological work in India during the period under review has been confined mainly to taxonomic work, the ecological aspect has not been altogether neglected. The morphological aspect will be dealt with in detail in this Outline on another page.

Ecology

Annandale (1915–1919) was perhaps the pioneer in India in regard to the study of the ecology of aquatic Insects, and his contributions seem to have acted as a powerful stimulus on workers in this country. Hora (1927, 1930) investigated the Insect fauna of rapid streams with special reference to the adaptations to life in such an environment. Pruthi (1931, 1933) studied the influence of different concentrations of hydrogen ions and temperatures of freshwater on mosquito larvæ and made a special investigation of the Insect fauna of certain highly saline ponds and tanks of the Punjab Salt Range. The same author (1924, 1926) investigated the influence of feeding, starvation, accumulation of CO_2 and other factors on the metamorphosis and moulting of Insects. Sen (1935) observed the effect of seasonal conditions such as temperature, etc. on the emergence of Anophelines. The effect of increased nitrogenous content of the soil in tea-plantations of Ceylon on the shot-hole borer *Xyleborus fornicatus* was studied by Jepson and Gadd (1926). Andrews (1923) showed that the ravages of the Capsid bug, *Helopeltis thievora,* on the tea plant can be minimized by the application of soluble potash to the roots of the tea-bushes. Sen studied the relationship of a meal of blood and ovulation in all species of Culicidæ. The reactions to chemical stimuli were studied by some authors. Howlett (1915) showed experimentally that the males of the Indian fruit flies of the genus *Dacus,* are attracted by certain odours of plants like mango and papaya, and that their movements can be controlled in any desired direction by the use of chemical substances having odours similar to those of the plants. Imms and Husain (1920) experimented on Dipterous flies in regard to their attraction to substances like ethyl alcohol with slight traces of acetic, butyric and other acids. Ballard (1923) has studied the reactions of the paddy borer moth (*Schoenobius*) to light and shown that in light traps a much larger number of females than males is caught.

Economic Entomology

The economic aspects of Entomology may now be considered in a little more detail indicating the part that Insects have played in this country as pests of crops, forest trees, stored grains, and as carriers of human and animal diseases. About the end of the 19th century the Government and the general public began to realize the economic value of Entomological studies, and during the twelve years between 1888 and 1899 the Entomologist attached to the Indian Museum at Calcutta published a series of papers on various Insect pests in addition to his studies on systematic Entomology in the journal called *Notes on Economic Entomology,* later issued under the name *Indian Museum Notes.* He was subsequently transferred to the establishment of the Imperial Agricultural Research Institute then in Pusa, but removed to New Delhi in 1936. The results of Entomological

Insects as crop pests

investigations in the Institute published for a long time chiefly in the *Agricultural Journal of India*, the *Memoirs of the Department of Agriculture in India*, and the *Bulletins of the Pusa Institute*, etc. are published from 1931 under the authority of the Imperial Council of Agricultural Research. The Entomological collections of the Imperial Institute are a store-house of knowledge from which Entomologists working not only in Indian provinces but also in the neighbouring tropical countries draw freely. As is widely recognized, the study of habits and habitats of Insects and their immature stages is absolutely essential for devising suitable control measures against noxious species. Between the years 1912 and 1937, several thousands of Indian Insects have been reared at the Institute and valuable data regarding their immature stages obtained and published. The life-histories of the members of the Orders Microlepidoptera, Hymenoptera, Coleoptera and Diptera have been the subjects of important monographs published under the auspices of the Imperial Department of Agriculture and the Imperial Council of Agricultural Research.

In addition to the preparation of monographs, a considerable volume of research work on the bionomics and control of several serious pests of crops has been done. Data regarding the life- and seasonal-histories, and the nature and extent of the damage done to crops in different parts of India were obtained in regard to the following: the bollworms of cotton, the voracious pests popularly known as cut-worms (*Agrotis* spp.), and the borers and hoppers of sugarcane and rice, and various other species of crop pests. Between the years 1915 and 1920 the Imperial Institute carried out some investigations on the pests of stored grain, and on the notorious termite pests of crops. In recent years important research work of a pioneer nature in India has been initiated by the Institute on the Insect vectors of virus diseases of plants. During the years 1935–37 the Insect vectors of diseases in tobacco have been studied and the results are expected to be published in the Indian Journal of Agricultural Science.

The Entomological investigations of the Madras Agricultural Department have been carried on for nearly twenty-five years, and have resulted in considerable increase in our knowledge of the crop pests of South India of which the more important are the following: the Stem-borer (*Schoenobius bipunctifer*), the Swarming Caterpillar (*Spodoptera mauritia*), the grass-hoppers of paddy, the pink boll-worm of cotton, the cocoanut caterpillar (*Nephantis serinopa*), the hairy caterpillar (*Amsacta* spp.) of millets, the Deccan grass-hopper, etc.

The Punjab Agricultural Department commenced research work on Insects in 1919 and completed extensive and fruitful investigations on the following pests: Pink boll-worm, white-fly (*Bemisia gossypiperda*), and leaf-roller (*Sylepta derogata*) of cotton, top-shoot borer and *Pyrilla* of sugarcane, pod caterpillar (*Heliothes*

obsolita), red pumpkin beetle of cucurbit gourds, Citrus *Psylla* and Citrus White-fly (*Dialeurodes citri*), fodder caterpillars (*Amsacta moorei* and *Laphygma exigua*), mango hoppers, etc. Of these, special mention must be madė of the fodder caterpillars, Citrus *Psylla*, and White-fly against which the Department has carried out successful large scale operations for several years. The rôle of birds as beneficent agents in keeping down the numbers of injurious Insects in a given area has been realized for a long time, and this Department has consequently devoted considerable attention to the study of such birds.

The Bombay Agricultural Department at Poona has done some useful work on the Thrips infesting chillies and on the spotted boll-worms of cotton. The U.P. Department of Agriculture has carried out large scale operations (heating of seed, etc.) against the pink boll-worm of cotton.

The rapid progress in the study of cotton pests in various provinces of India is chiefly due to the initiative of the Indian Central Cotton Committee which has given adequate financial assistance to schemes promoting the study of these pests. The Imperial Council of Agricultural Research has within the last two years encouraged the study of the Insect pests of some other crops as well by making small grants to individuals, associations and universities on approved schemes of research.

Insects as pests of forest trees

The research work on Forest Entomology has been restricted mostly to the Imperial Forest Research Institute, Dehra Dun, established in 1906. This Institute has built up a rich collection of forest Insects consisting of about 16,000 species, and published valuable information in the *Indian Forest Recorder* and other journals about their biology and occurrence in different parts of the country. In addition, several forest pests have been intensively studied with a view to control them. A brief account of these studies is given below: The heart-wood borer, *Hoplocerambyx spinicornis*, of *Shorea robusta* is one of the most injurious species in natural forest. Standard control measures have been prescribed, of which the trap-tree method is perhaps the most interesting; trees are felled during the period of flight of the beetles and the vast numbers that are attracted are destroyed. It would appear that, as a general rule, direct methods of control, such as the use of insecticides, automatic trapping, etc. must be ruled out in forest Entomology, as most of the routine control measures devised have to be modified to suit silvicultural conditions. Owing, however, to the relatively higher value of converted timber, conditions for the control of borers are more favourable at the stage when direct methods of control are applicable.

The problem of defoliators and the feasibility of applying methods of biological control in respect of these pests have been studied at Dehra Dun with reference to the distribution and iology

of their parasites and predators; and from the early months of 1937 extensive field operations have been carried out. The living parasites of teak defoliators are being interchanged between Nilambur in Madras and Burma, and the parasites of defoliators of Sissoo and Mulberry in the Punjab plantations are being artificially multiplied and distributed.

The Spike disease of Sandal has presented a difficult problem to the Forest Institute, and as a first step towards its solution the fauna of the Sandal tree in various parts of the country has been studied extensively. Of the thousands of species found commonly on this plant, only a few are at present considered to be the possible vectors of the Spike disease. The further investigations on these vectors are being carried on by the Madras Forest Department.

The Insect pests of forest trees are mostly immature stages, and the application of the methods of identification in vogue for the adult Insects to the immature stages has proved unsatisfactory in practice. It has, therefore, been thought that a classification based on the study of the larvæ and other immature stages would be more valuable in the identification of forest pests than the one ordinarily in use. This aspect of Forest Entomology has received considerable attention in recent years at the hands of Gardner, Entomologist at the Dehra Dun Institute, who studied the Coleopterous larvæ and contributed many papers on the subject. Similar work on the Lepidopterous larvæ is also in progress.

Insects as carriers of diseases to human beings and domestic animals

Patton and Cragg (1913) in their work, *A Text-book of Medical Entomology*, have embodied all available information on pests of medical and veterinary importance in India. The modern systems of treatment of tropical diseases tend more and more towards the control of Insect vectors of these diseases. The outstanding researches on Arthropods in relation to human diseases in India have been carried out chiefly under the auspices of the Indian Research Fund Association at the Central Research Institute, Kasauli, the School of Tropical Medicine, Calcutta, and the King Institute of Preventive Medicine at Guindy, Madras. The Insect-transmitters of three of the important human diseases common in India, namely, Malaria, Kala-azar, and Plague have been extensively studied. The works of Christophers, Barraud and their associates who were the first to study the entomological aspects of Malaria and to carry out exhaustive surveys of Anopheline and Culicine Mosquitoes in India have been referred to already. The results of their investigations were embodied in the Government of India *Health Bulletin* published from time to time. Strickland, Puri, and others have given systematic accounts of the larvæ of Anophelines with synoptic tables for their identification. Senior-White, Iyengar, Pruthi, and Mehta studied the physical factors in relation to the ecology of mosquitoes and showed that the various species of Anophelines respond differently to the

chemical constituents of waters in which they breed. Covell wrote a very useful book entitled *Anti-Mosquito Measures*. The Indian Kala-azar Commission carried out considerable research work on the possible rôle of Insects in the indirect transmission of Kala-azar. The bed bug, *Cimex hemiptera*, *Triatoma fasciata*, and sand-flies of the genus *Phlebotomus* were suspected as transmitters of this disease. Experimental investigations have, however, removed the suspicion on several species of Insects and fixed the species of *Phlebotomus* as the possible culprits.

Surveys of fleas have been conducted in various parts of India in connection with research work on Plague. In addition to the papers on fleas by Sharif and Iyengar which have been already referred to, Mehta's work on the fleas on rats of the Simla Hills as possible vectors of Typhus, the work of the Indian Plague Commission on transmission by fleas, and Goyle's recent work on the distribution of species of fleas in relation to the incidence of Plague may be mentioned.

The causal agent of filarial infection has been traced to the mosquitoes by King, Pandit and their collaborators who demonstrated the development of the filarial parasite in *Culex fatigans*. Cragg who was the first to investigate louse-borne Typhus was himself the victim of that disease. Very recently Covell and Mehta demonstrated the rôle of the rat-flea, *Xenopsylla cheopis*, in the transmission of Typhus of the X 19 type. In a series of papers, Megaw showed that the tick might be a possible vector of Typhus in the Simla Hills.

Patton and Cragg have referred to the pests of domesticated animals in their book. Since this work was published the Imperial Agricultural Research Institute has gathered valuable information on Insects injurious to cattle and other domesticated animals. The contributions of Sen, Patel, Isaac (1925, 1933), and Bhatia on the life-histories of various species of Tabanidæ and other blood-sucking flies found on cattle and other domesticated animals are of great value. The Imperial Veterinary Research Institute at Muktesar and the Provincial Veterinary Departments have done important work on the Insects concerned in the transmission of diseases to animals, a greater part of which being directed to a search for vectors of Surra and Rinderpest. Cross and Patel and Kahan Singh observed that Surra was mechanically transmitted by some Tabanid flies, while Bhatia demonstrated the transmission of Rinderpest by *Tabanus orientalis*.

Insects as promoters of Industry

The extent of destruction caused by Insects pales into insignificance when we consider the enormous possibilities for production of wealth which Indian Insects offer to this country. India already holds the world monopoly for Shellac which is a product of the activity of the lac insect, *Laccifer lacca*. Pioneer work on this Insect and on lac culture was undertaken at the

Imperial Agricultural Research Institute between the years 1912 and 1925, as a result of which the facts concerning the habits, life-history, and enemies of the lac Insect formed the subject of a memoir published by the Institute. In this memoir the detailed methods of lac cultivation were explained with a view to make them intelligible to the cultivators.

The realization of the importance of the Lac industry to the country led to the establishment in 1925 of the Indian Lac Research Institute at Ranchi, in which the lac Insect, its plant hosts, the chemistry of lac, and other cognate subjects are being intensively studied. Among subjects relating to the lac Insect itself may be mentioned the investigations on the anatomy of both the sexes, the influence of temperature on oviposition, the incubation and emergence, and the swarming of larvæ. The female of the Insect has been found to be capable of parthenogenetic reproduction which does not seem to adversely affect, among others, resin production and the fertility of the species. The major predatory enemies of the lac Insect, namely, *Eublemma amabilis* and *Holococera pulverea*, have been known to be attacked in the field by several species of Insects of which *Microbracon greeni* seems to be the most important. With a view to control the depredations of the predators by biological methods, this species as well as its near ally *M. hebetor* are being studied in detail.

The rearing of Silkworms is a very ancient industry in India, more particularly in Kashmir, Bengal, and Mysore, but the industry was declining at the beginning of the present century owing to the adoption of primitive methods of culture. Between the years 1912 and 1924 experimental work on (1) the rearing of Indian silkworms under hygienic conditions, (2) the prevention of diseases to which the worms were susceptible, and (3) the cultivation and improvement of mulberry was carried out by the Imperial Agricultural Research Institute. As experience showed that Sericulture could be practised best as a cottage industry in the Indian villages, bulletins in several languages were issued by the Institute for the benefit of rearers all over the country. The expansion of the industry led the Departments of Agriculture of the various provinces in India to study the silkworm under local conditions. Although Sericulture was a well-established subsidiary occupation of farmers in parts of India where the rearing of silkworms was possible, the importation, in recent years, of cheap artificial silk has adversely affected the silk industry in India.

Bee-Keeping

Honey is in great demand in India both as food and as medicine, and considerable quantities are imported from New Zealand and America. Neither bees nor the suitable plants on which they feed are lacking in India, yet the quality of local honey available in the Indian market is often poor because of the defective methods in vogue of extracting honey. An attempt to place bee-keeping on a scientific basis was made

by the Imperial Agricultural Research Institute in the early decades of the present century, and useful bulletins on the subject in the principal Indian languages served to popularize the industry. As a result we now find bee-keeping as a subsidiary industry not only popular amongst the village folk but also amongst educated youths in the country. The Imperial Agricultural Research Institute has in recent years answered innumerable enquiries regarding scientific bee-keeping and has supplied standard bee-hives, comb foundation sheets, and other bee-keeping appliances to numerous correspondents all over the country. The Departments of Agriculture in the Punjab and Madras maintain model apiaries run on modern lines for purposes of demonstration.

IX. Arachnology.

The progress of Indian Arachnology between the publication in 1900 of the volume on Arachnida in the *Fauna of British India* series, and the inauguration of the Indian Science Congress had been slow, but from 1914 onwards a steady progress in all branches of Arachnology has been observed. Gravely in a series of papers between 1915 and 1935 has contributed a great deal towards our knowledge of the Indian Arachnida in general and the Spiders (Aranæ) in particular. Among these may be mentioned his papers on the Indian Mygalomorph spiders (1915, 1935), on the Indo-Australian Thelyphonidæ and the problems of evolution connected with them (1916), on the spiders of the sub-family Tetragnathinæ and the family Lycosidæ (1921, 1924), and on the families Ctenidæ, Sparassidæ, Selenopidæ, and Clubionidæ (1931) besides several other smaller papers on the spider fauna of India. Henderson and Sheriffs (1919, 1929) added to our knowledge of S. Indian Arachnids in general. Caius (1930-1931) contributed an interesting paper on the toxicity of the venoms of various Indian scorpions. Bahl's (1915) papers on the Ant-like spiders of the family Attidæ, and Hingston's (1920, 1923, 1927) and Sukh Dayal's (1931) observations on the habits of orb-weaving and other spiders, and Bhattacharya's (1934) on the habits of Bengal spiders are noteworthy. Mathew (1931, 1934) has made valuable contributions on the life-history of certain *Myrmarachne* which mimic the red-ant (*Oecophylla*) and others during the various stages of their life-history and on the colour changes in the eyes of certain Attid and Thomisid spiders due to the great mobility of the ommateum of the eye. Our knowledge of the Indian Opiliones and Palpatores is due almost entirely to the studies of Roewer (1924, 1929). Comparatively little is known of the Indian Acarina, but Viets (1926), Walter (1928), and Jacot (1933) contributed to our knowledge of the Indian water-mites and moss-mites. Ellingsen (1914) gave an account of the Indian Pseudoscorpionidea while Hett (1921, 1923) gave short accounts of Pentastomids. Sharif (1924,

1928, 1934) dealt with the morphology and bionomics of the common Indian Tick (*Hyalomma aegyptium*), and revised the Indian Ixodidæ indicating the relationship of the genera.

It would be convenient to include here a review of the progress of our knowledge in regard to the Myriapoda which is due mainly to the researches of Silvestri (1916–1929), Chamberlain (1920), Attems (1936), Verhoeff (1930, 1936) and Carl (1932, 1935). The large number of new genera and species of Diplopoda described in recent years and the absence of many of them from other parts of the world strongly suggest a high degree of endemicity of Indian forms. Bonnell (1929), and Hingston (1930) have contributed valuable observations on the habits of various Myriapods.

X. Ichthyology.

The study of Fishes in India seems to have attracted attention from ancient times as shown by Hora (1935) who has discussed the extent of knowledge of the ancient Hindus in regard to the correlation of form of fishes to their environment and modes of locomotion. The history of Ichthyological studies in more recent times has been ably summarized by Chaudhuri (1917), and should prove to be of value to those interested in this aspect of Ichthyology.

The fish-fauna of India is so closely related to that of other countries which form part of the Oriental Region that any advance in Ichthyology in the neighbouring territories influences the progress of the science in India. The most outstanding advance of this kind during the last quarter of a century has been the magnificent work of Max Weber and de Beaufort (1911–1936) on the *Fishes of the Indo-Australian Archipelago*. This work is not yet complete as accounts of several important groups of marine fishes are still under preparation. The best tribute to this work is the fact of its having stimulated the investigations on the fish-fauna of Siam by Hora (1923), Smith (1927–33), Suvatti (1936), and Fowler (1933–37), of Indo-China by Pellegrin (1935-36), Chabanaud (1926) and Chevey (1929–1934), and of China by a large number of Chinese workers, Chu, Fang, Kimura, Lin, Tchang and others (1930–37). These studies have resulted in the compilation of useful indices and lists of fishes of the various regions and in the intensive study of certain groups of freshwater fishes. The faunistic surveys have also given considerable impetus to the study of geographical distribution and phylogenetic relationship of fishes of the Oriental Region, and valuable contributions on these subjects by Mori (1936), Hora (1937), and others have already appeared.

In India including Burma and Ceylon, Day's works, the *Fishes of India*, and the two volumes on fishes in the *Fauna of British India* series, though out of date in many respects, are still the only standard works on Indian Ichthyology. Modern literature on this subject is considerably scattered, and is likely to be brought

together only when the revised *Fauna* volumes now under preparation by Hora are published. In this connection Hora (1933–36) has published a series of critical studies of freshwater Siluroid fishes which will prepare the ground for a revision of the genera included in the family. During the last 25 years the study of Indian fishes has been confined mainly to freshwater forms, but a few reports and notes on marine fishes by Sewell, Raj, Southwell, Prashad, Chaudhuri, Duncker, Hora, Mukerji, Fowler, Lele, and Norman have also appeared in the *Records* and *Memoirs of the Indian Museum* and other Indian journals in this period. Among the papers on marine and estuarine fishes several, such as those by Chaudhuri (1916–1923) and by Hora (1923) on the fishes of the Chilka Lake, by Hora (1933), and by Ayyar and his co-workers (1935) on estuarine Gobies, are of interest, and reveal the great range of physiological adaptability of marine fishes to changes in salinity. In their study of marine fishes of the Tavoy coast, Burma, Hora and Mukerji (1936) have found several species of unusual zoogeographical interest with a discontinuous distribution which corroborates to some extent Alcock's analysis of the distribution of Indian marine genera. Reference to advances in marine Ichthyology has already been made (*vide*, p. 373).

The period under review is notable for the advances in our knowledge of the freshwater fishes with special reference to their distribution, ecology, and bionomics. A host of workers, including among others, Annandale, Chaudhuri, Hora, Raj, Prashad and Mukerji, have extended our knowledge of these fishes from the taxonomic point of view apart from making known the regional fish fauna of Indian lakes and mountainous regions. It would be of advantage in this connection to deal briefly with the fish-fauna characteristic of each of the regions in which special investigations had been carried out.

The fishes of the freshwater lakes have been studied by Annandale (1918), Hora (1921), and Prashad and Mukerji (1929, 1930). The fish-fauna of the Inlê Lake of the S. Shan States, Burma, has an isolated element consisting of certain peculiar genera and species one of which belongs to a new family. The most characteristic fishes of the lake are the eel *Chaudhuria* of the group Opisthomi and small Cyprinids of the new genera *Microrasbora* and *Sawbwa*. The physical conditions of the lake and the geographical relations of the forms peculiar to it lead to the conclusion that the fish-fauna is essentially an isolated one. The Indawgyi Lake of Upper Burma and its connected waters have, in addition to a large number of species of wide distribution, certain endemic forms whose relationships with their congeners elsewhere are at present obscure. A new family had been erected to receive one of the species of fish, *Indostomus paradoxus*. Bolin (1936) has discussed the systematic position of the genus and pointed out that its nearest relatives are among the Hemibranchii or Gasterosteoidea.

The eel, *Chaudhuria*, previously known from the Inlê Lake has also been found in the freshwater areas connected with the Indawgyi Lake. The fish-fauna of the Loktak Lake in Manipur, Assam, includes no specialized forms, but only a few which belong to a dozen species of fairly wide distribution. The Manchar Lake of Sind has a much larger number of species of more or less wide distribution. It is thus clear from the foregoing that the Burmese Lakes which have specialized forms of fish are of great antiquity, while the Indian Lakes which have no endemic element in their fish-fauna are of comparatively recent origin and contain only species of wide distribution.

Regional surveys of the fish-fauna have been fairly numerous during this period, and the Indian Region may be conveniently divided into three sub-regions for the purposes of this account, namely: (1) the Peninsular region south of the Vindhya Range, (2) the Indo-Gangetic plains, and (3) the extra-Peninsular region comprising the Himalayas and the adjacent hill-ranges east and west of them.

In the Peninsular region, the fish of Madras were dealt with by Raj (1916), the Chiclid fishes of Malabar by Panikkar (1921), those of small streams in the Bombay Presidency by Annandale (1919), those of Mysore and Coorg by Hora (1937), those of Hyderabad State by Rahimullah and Das (1935), those of Deolali by Hora and Misra (1937), of Travancore by John (1936) and of Ceylon by Deraniyagala (1929–1934) and Vasiliu (1931). The fish-fauna of this region is extraordinary in having a fair representation of Far-Eastern species which do not extend normally beyond the Teesta valley in N. Bengal. Hora (1937) has offered a geological explanation for this anomaly in distribution. The differential uplift movement of the Himalayas at the junction of Nepal and Assam during the Miocene or some later period is supposed to have interfered with the free movements of the fish-fauna along the 'Indobrahm' of Geologists, and deflected their progress along the Satpura trend which, probably, at this period still stretched from the Himalayas to Gujarat and thence along the Western Ghats to the hills of S. India.

The fishes of the Indo-Gangetic plains have been comparatively little investigated, but all that is known of the fish-fauna of this region indicates that the forms which occur here are of very wide distribution. The food-fishes of the Punjab (Hamid Khan, 1931) and the fishes of Manchar Lake (Prashad and Mukerji, 1930) are among the more recent contributions pertaining to this area.

The extra-Peninsular region has provided a wealth of interesting forms. The fish-fauna of the Burmese Lakes and the Loktak Lake in Assam has already been referred to. It now only remains to mention the investigations into the fish-fauna of the Inlê basin (Annandale, 1918), Abor Hills and Putao plains (Chaudhuri, 1913, 1919), Assam and the Shan States of Burma (Hora, 1923–25),

Upper Burma and the Indawgyi basin (Prashad and Mukerji, 1929), and of Seistan, Afghanistan, Chitral, and Tibet (Annandale, 1920, Hora, 1920–36 and Mukerji, 1936). This region has provided Hora with the opportunity of studying the hill-stream fishes, and of revising in a comprehensive manner the hill-stream genera and families, *Psilorhynchus*, *Garra*, *Nemachilus* and *Aborichthys*, and the Homalopteridæ and Sisoridæ respectively. The fish collections of the Third Netherland Karakoram and the Yale North India Expeditions which were studied by Hora and Mukerji (1935, 1936) belong mostly to this region.

The advances in the study of morphology of fishes during the period under review are of importance, and pertain mostly to the skeletal, respiratory and circulatory systems of fishes, both marine and freshwater. These are referred to in the section on morphology in the present Outline, and consist of short communications on various aspects of morphology to the zoology section of the Indian Science Congress.

Considering that the study of the developmental history of fishes is of great importance in solving fishery problems, it seems surprising that so little attention has been paid to this subject in India. Reference may, however, be made to the contributions of Bhattacharya (1916) on *Petroscirtes* and *Hemirhamphus*, of Rao (1918) on *Ophicephalus punctatus*, *Callichrous bimaculatus*, *Notopterus notopterus*, of Southwell and Prashad (1919) on the intra-uterine embryos of Selachians, of Hamid Khan (1923) on *Labeo rohita*, *Cirrhina mrigala*, *Carassius auratus* and other species, of Aiyar (1935) on *Acentrogobius neilli*, of Rao (1934) on *Therapon jarbua*, of Ahmed (1934–36) on *Wallago attu* and *Labeo gonius*, and of Jones (1937) on *Etroplus maculatus* and other species, *Acentrogobius viridipunctatus*, *Boleophthalmus boddaerti*, *Petroscirtes bhattacharyæ*, *Aplocheilus melastigma*, and *Panchax parvus*.

The attention of the Indian public has been drawn in recent years to the economic importance of fish as food of value to the undernourished populations of this country. During the last quarter of a century, research on problems of fisheries *sensu stricto* has received scant attention except in a few centres. The Madras Fisheries Department which is perhaps the only well-organized institution of its kind in India has devoted itself to various aspects of Fisheries under the direction of Hornell and Raj. *Catla* has been introduced into the Cauvery, the breeding habits of *Hilsa* and other migratory fish such as the oil-sardines (*Clupea longiceps*), Mackerel (*Scomber microlepidotus*), and of the flying-fish have been observed, and preliminary work on various other problems of fish-culture has been completed. For a fuller appreciation of the work of the Department, the reader is referred to its Reports and Bulletins published from time to time. The Punjab Fishery branch of the Agricultural Department which has been in existence for several years has concerned itself in part with the habits and breeding of

some of the common freshwater food-fishes (Hamid Khan, 1934(. The Fishery section of the Bombay Industries Department which has recently been inaugurated is at present mainly concerned with the marketing of marine fish, but the culture of *Catla, Megalops*, etc. in inland waters has also been taken on hand. Bengal with its extensive waterways, estuaries, and large rivers has at present no fishery organization, but the one that existed before 1920 studied problems of inland fishery. Southwell and Prashad, under the auspices of this Department, made preliminary investigations in regard to the breeding grounds of the *Hilsa* fish without appreciable results.

The types of fishing implements used and the methods of fishing adopted in various parts of the country have been the subjects of study by several authors. Annandale (1918), Hora (1921, 1923), Hamid Khan (1930), Chopra (1927) and John (1936) have dealt with the methods and implements of fishing in the Inlê Lake, in the Loktak Lake and the vicinity of Calcutta, in the Punjab, in the Indawgyi Lake, and in Travancore respectively.

The ecology of fishes in different environments has been studied by various authors. The structural adaptations, particularly of the organs of attachment, of fishes to life in rapid hill-streams have been investigated by Hora (1930), while the behaviour of air-breathing fishes under different adverse conditions in their environment has been investigated by Das (1927, 1934) and Hora (1935). Kemp (1917) drew pointed attention to the resemblance of certain estuarine fishes to deep-sea forms living under similar physical conditions. The lack of light due to depth in the case of the sea and to the presence of muddy water in that of the estuary, and the occurrence of a loose shifting substratum at the bottom in both cases have brought about similar adaptations in various species of fish either closely or remotely related.

The sudden mortality of fish in seas, tanks, lakes and ponds seems to be a common and widespread phenomenon. Hornell (1917) and Hornell and Nayudu (1923) described cases of widespread mortality among marine fishes due to Protozoa. Other causes of such mortality were investigated by Sewell (1927) and Pruthi (1932) in Calcutta, and by Chopra (1927) in the Indawgyi Lake of N. Burma. The rise in the CO_2 content of the water and, probably, a reduction in the amount of free oxygen brought about by meteorological conditions were held to be responsible for the mortality. Pruthi suggested that in addition to these factors, the poisonous by-products of putrefaction of organic matter at the bottom of tanks may also be responsible for fish-mortality in the cases investigated. Chopra holds the view that excessively muddy water may be responsible for deaths amongst fish that have no accessory respiratory apparatus, and that the poisoning of the gaseous contents of the water by putrefaction may cause sudden mortality in many species of fish.

The rôle of fish as destroyers of aquatic arthropods which act as carriers of disease to human beings has been recognized for several years. This subject has received recognition in India in recent years. Moorthy has controlled the incidence of Guinea-worm infection in Mysore by introducing small species of *Barbus* in tanks, ponds and wells. The introduction of the Tropical American Poecilid fish, *Gambusia*, into India to combat mosquito-borne diseases has been attended with some success. The use of indigenous species of fish in this connection has been advocated by Prashad, Hora and others. The food of these fishes in various environments has been investigated by Sen (1937), and Hora and Nair (1937).

XI. Herpetology.

A wider and more systematic study of the Reptiles and Batrachians of India in regard to distribution, habits, morphology and life-histories of a large number of species has increased in recent years the bounds of our knowledge of Indian Herpetology to a considerable extent. With the adoption of new systems of classification the volume on Reptilia and Batrachia in the *Fauna* series by Boulenger published in 1890 was considered out of date, and the publication of the revised volumes by Smith, M.A., dealing with various orders of Reptilia and Batrachia which was commenced in 1931 has ushered in a new era of progress. The Reptilian Orders Loricata (Crocodiles), and Testudines (Tortoises and Turtles) are dealt with in the first volume (1931) and the sub-order Sauria (Lizards) of the Order Squamata in the second volume (1935). The volumes dealing with the remaining Squamata (Snakes) and the Batrachians are expected to be published shortly.

Batrachia.—Several papers dealing with the morphology, development, and classification of the frogs, toads, and Cæcilians have been published in India. Of these, however, the most important is the monograph by Boulenger (1920) of the genus *Rana* which has a wide range not only in Indo-Malaya but also in Melanesia and N. Australia. The morphological papers are referred to on another page. The adult forms and tadpoles of various families of frogs and toads have attracted the attention of several workers. Smith (1924, 1935) studied the Indian and Indo-Chinese tadpoles and the Amphibians of Upper Burma. Annandale (1915, 1918, 1921) gave an account of the Batrachia common in the islands and on the shores of the Chilka Lake, and of the tadpoles of S. Indian Hills. The same author in collaboration with Rao (1918) studied several South Indian Batrachia, while the latter (1918) gave an account of the tadpoles of Indian Engystomatidæ giving a key for the identification of the larvæ. Wall (1922) gave an account of the frogs of the Nilgiri Hills. Chabanaud (1919, 1922) dealt with the Batrachia of the plains and of the Western Himalayas, and Roux (1928) with those of

South India. Hora and Chopra (1923) referred to the poverty of the Batrachian fauna of the Punjab Salt Range. Hora (1922) contributed a very interesting study of the functions of the oral apparatus of the tadpoles of *Megophrys parva*.

Reptilia.—The lizards, snakes, and turtles have received considerable attention during the period under review. There are numerous references to the habits of several species in the *Journal of the Bombay Natural History Society*. Annandale (1914, 1915, 1917) described the reptilian fauna of the Himalayas, the Abor country in the N. East of India, and of the Chilka Lake. Among others who have contributed to our knowledge of the reptilian fauna of the country are Prashad (1914) on the lizards of the Simla Hill States, Chabanaud (1919, 1922) on the reptiles of British India and W. Himalayas, Deraniyagala (1929, 1931, 1932 and 1934) on the Ceylon Geckonid lizards and the fossorial skinks, Hora (1926, 1927) on Indian lizards of the families Geckonidæ, Agamidæ and Scincidæ, Hora and Chopra (1923) on the reptiles of the Punjab Salt Range, Wall (1922) on the lizards of the Nilgiris, Roux (1928) on the reptiles of S. India, Henry (1928) on the Geckoes, and Smith (1937) on a review of the Scincid genus *Lygosoma*. The habits of the Ceylonese crocodiles and turtles and the problem of evolution in the Testudinata were studied in detail by Deraniyagala (1930), while the Chelonia of the Indus system were described by Prashad (1914). Smith (1929) has contributed interesting articles on the survival of the Gharial and on the Monitor lizards of the upper reaches of the Brahmaputra. Asana (1931) has observed in detail the habits of *Calotes versicolor*. The Indian snakes have been studied in great detail by Wall, among whose contributions are his reviews of the Indian species of *Amblycephalus* (1922) and of *Oligodon* (1923), and his studies of the snakes of Ceylon and of Burma (1921, 1925). Rao (1917) studied the South Indian pit-vipers of the genus *Lachesis*. The studies of Fraser (1936-1937) on the snakes of Deolali with special reference to the Osteology, dentition and habits are also of importance.

XII. Ornithology.

One outstanding contribution to Indian Ornithology during the last twenty-five years has been that of Stuart Baker (1922 to 1930) on Birds of the Indian Empire in the *Fauna of British India* series. Before the completion of this monumental survey, ornithological studies in India were dominated by the first edition of the same work, compiled by Blandford and Oates (1889 to 1898).

It is a feature of ornithological studies in India that they fall into well-defined periods, each marked by the appearance of an important and comprehensive work in which the researches of the previous period are embodied, and which furnishes the starting point for further studies. Thus the first or pioneering epoch of

Indian Ornithology may be said to have culminated with the completion of Jerdon's *Birds of India* (1862 to 1864). Its publication was followed by detailed and specialized studies undertaken by a large number of workers, the place of honour among whom is occupied by Allan O. Hume, a keen and distinguished ornithologist. Then came the first edition of the *Fauna* by Blanford and Oates, which was the standard work on Indian Ornithology for over quarter of a century, during which it served as a background for further studies by a host of field naturalists and specialists, whose efforts were all directed towards supplementing the information given in it. And last of all came Stuart Baker's work, which may be said to have opened the fourth period of Indian Ornithology.

The most important innovation introduced in Stuart Baker's work was in regard to nomenclature and classification. The binomial system of nomenclature adopted by Blanford and Oates which served its purpose well enough in its day as a guide to field naturalists was at a great disadvantage in lagging behind the progress of Ornithology in other countries. It afforded no scope for indicating subspecific differences due to geographical isolation or climatic variations. It was in recognition of both these needs for reform that Stuart Baker adopted the trinomial system for his edition of the *Fauna*. In doing so he defined a species as forms or groups of forms with no known direct connection with other forms or groups of forms. He recognized subspecific or geographical forms when they differed in degree either in size, colour, or some other characteristic from the forms with which they were most closely connected, but were themselves constant within a given area though linked with these forms by others which were intermediate.

The adoption of this principle has naturally involved some modification of the classification previously in use. Thus forms which had the status of species came to be recognized as no more than subspecies or geographical races, resulting in the reduction in the number of species. The numerous changes made in the previous nomenclature owing to a stricter application of the 'laws of priority' were an inconvenient necessity for laying a firm foundation on which Indian Ornithology could be built.

It is of interest to note that with the addition of 53 forms in his final Addenda volumes, the number of Indo-Burmese species and subspecies dealt with by Stuart Baker comes to a total of 2,346. Hartert in his admirable work on the Palæartic Avifauna recorded only 3,198 species and subspecies for the whole of the Palæartic Region, whilst Sclater in his two volumes of *Systema Avium Aethiopicarum* admits 4,561 species and subspecies for the Æthiopian Region, a comparison which shows the extraordinary wealth of bird-life in the Eastern Tropics.

In addition to the *Fauna* volumes Stuart Baker published his *Game Birds of India* (which originally appeared and is still appearing as articles in the *Journ. Bombay Nat. Hist. Soc.*) between 1921 and

1930 in separate volumes and his *Nidification of Birds of the Indian Empire* (1932–1935) in four volumes. This last is a monumental and indispensable work on Indian Oology, incorporating the great progress which has been made in this important branch of Ornithology since the publication of Oates' edition of Hume's *Nests and Eggs* in 1889. Hume's *My Scrap Book: or Rough Notes on Indian Oology and Ornithology* (1869) showed how little was then known about Indian Oology, and paved the way for his '*Nests and Eggs of Indian Birds*' which gave a great impetus to the study of the subject, and was the basis of Oates' publication referred to above.

During the period between Oates' edition of the *Fauna* and Stuart Baker's revised edition a large number of ornithologists including Stuart Baker himself, published the results of their observations on the nesting habits of Indian birds in works on Ornithology or in periodicals. Stuart Baker's carefully gathered collection furnished the basic material for the work which in the width of its range and thoroughness is one of the greatest single achievements in Indian Ornithology.

Ornithological researches of the highest scientific value by other authors have appeared from time to time in the pages of the *Journal of the Bombay Natural History Society*, and in *Ibis*, the organ of the British Ornithological Union, and it is to these journals that one must turn for a proper appreciation of the progress of knowledge on the Birds of India.

Regional surveys have contributed a great deal to our knowledge of Indian Birds. Thus the birds of the Western Himalayas, the Punjab, Kashmir, and the adjacent regions both to the East and the West have been carefully and systematically described by Hugh Whistler. The great merit of Whistler's researches lies in the collection of a great mass of detailed information bearing on the features of zonal distribution and migration and other movements of various species of birds along the Himalayas and the neighbouring ranges which came under his observation. His studies further indicate how such movements have a definite bearing on the status of the species. Ticehurst's painstaking studies afford complete data of immense value for the purpose of determining geographical races. Other notable workers on the avifauna of the north-west of India are Ward, Donald, Osmaston, Magrath, and Jones. The first two have described the Birds of Kashmir and the Birds of prey of the Punjab respectively. A monograph which no one concerned with the Ornithology of the Himalayas can afford to overlook is Meinertzhagen's *Some Biological Problems connected with the Himalaya*. Mention should also be made in this connection of his *Birds collected in Ladak and Sikkim* (1927), and of Ludlow and Kinnear's work *On the Birds of Bhutan and adjacent Territories of Sikkim and Tibet* (1937) which throw a flood of light on the birds of the Eastern Himalayas.

The birds of the Vernay Survey of the Eastern Ghats are being studied by Whistler and Kinnear, and the results of the studies when finally published will constitute a valuable contribution to our knowledge of the avifauna of the Eastern Ghats which had been so little studied by ornithologists in India.

An immediate beneficial result of the Vernay Survey has been the extension of regional surveys of S. India to the Nizam's territories and to Travancore and Cochin States. The taxonomic results of these surveys are being published by Whistler with field notes by Salim Ali.

The surveys just mentioned and the work done on the Punjab and Himalayan birds constitute the most important chapter in the history of ornithological progress in India within the last twenty-five years. But minor or regional surveys in various parts of India have also materially added to our knowledge of Indian Birds. Ticehurst studied the Birds of British Baluchistan and Sind, D'Abreu the C.P. birds, Steven those of Upper Assam and Sikkim Himalayas, and Hopwood and Stanford those of Burma. Harington's *Timaliidæ*, Gill's *Nests and Birds of Common Birds in the U.P.*, and Bates' *Birds Nesting with a Camera* are other contributions of the highest interest to ornithologists.

Last of all, mention should also be made of some popular or semi-popular works on the Birds of India, among which are counted Whistler's *Popular Handbook of Indian Birds* (second edition, 1935), Bates' *Bird Life in India*, Fletcher and Inglis' *Birds of an Indian Garden*, Wait's *Birds of Ceylon*, Holmer's *Indian Bird Life and Bird Study in India*, Law's *Pet Birds of Bengal*, and Dewar's and Finn's works. Though these are not to be classed as original contributions to Indian Ornithology, they have a place in serious ornithological literature as, by creating an interest in Indian bird life, they draw new recruits to a field whose full potentialities still lie unexplored.

In conclusion, reference must be made to the anatomical works on birds by Pycraft, Beddard, Lucas and others which have appeared from time to time in the *Proceedings of the Zoological Society of London* and other foreign periodicals and publications. But within the space available for this Outline it would be difficult to review them satisfactorily.

XIII. Mammology.

The study of Indian mammals was commenced somewhere about the second quarter of the nineteenth century by a band of enthusiastic workers consisting of Hodgson, Elliott, Hutton, McClelland, Sykes, Blyth, Jerdon, and Kelaart amongst others. The collections and studies of these workers formed the basis of Blanford's *Mammalia* in the *Fauna of British India* series (1888–

1891), but the interest in this group seems to have languished from about the middle of the 19th century till the first decade of the present century. Amongst the few that kept up their enthusiasm for the study of mammals were Anderson, Blanford, and others. The data in regard to the distribution of various species and their habits, and in regard to the extent of variation in individuals of varieties, subspecies, and well-known species were inadequate, and in contrast to the detailed knowledge of the mammals of other countries, the data on Indian mammals were considered unsatisfactory. With a view to make up the deficiencies in this respect, the Bombay Natural History Society launched a scheme in 1911 of a survey of the mammals of India, Burma, and Ceylon which, although by no means complete as yet, has brought together a great wealth of material which has kept several mammologists in India and abroad busy. The net result of these activities will be to replace the present out-of-date volume on Mammalia by Blanford in the *Fauna* series by an enlarged second edition by Hinton and Pocock which is expected to include no less than three volumes. The progress in our knowledge of the mammals of India is, therefore, in the main a history of the results of the mammal survey conducted by the Bombay Natural History Society which are in the form of notes on various species by different authors. To facilitate reference to the scattered papers published for the most part, fortunately, in the volumes of the *Journal of the Bombay Natural History Society*, a series of reports on the species of mammals collected in various regions, of summaries of such reports, and of the scientific results of the mammal survey have been compiled by Oldfield Thomas, Wroughton, Ryley, Hinton, Lindsay and Pocock and published in this Journal. It will be impossible, in the present account, to make more than a brief mention of some of the more important contributions on the subject of mammology during the period under review.

The interested reader is, therefore, referred to the volumes of this Journal for details on the subject. Amongst papers of a comprehensive nature are those on the squirrels of Upper Burma by Thomas and Wroughton (1916), on the House-rats of the Indian Empire by Hinton (1918–1920), on the synonymies, characters and distribution of the Macaque monkeys by Hinton and Wroughton (1921), on the systematic value of the glans penis in Macaque monkeys and on the external characters of some species of Indian Lutrinæ by Pocock (1921), on the House-rats of Nepal by Hinton (1922), on Indian shrews by Lindsay (1929), on the so-called colour phases of the rufous Indian Horse-shoe bat, *Rhinolophus rouxi*, by Anderson (1917), and the following important papers by Pocock—the Langurs or Leaf-Monkeys of India (1928), Tigers (1929), the Panthers and Ounces, and Lions of Asia (1930), the Macaque Monkeys of India (1931-32), the Black and Brown Bears of Europe and Asia (1932), the Palm Civets of the genera *Paradoxurus* and *Paguma* of India

(1933-34), the Foxes of India (1936) and the Mongooses of India (1937).

Besides these, several short papers on Indian mammals have been published by various authors in Indian journals, chiefly, the *Journal of the Bombay Natural History Society*. Some of these, apart from being taxonomic in format, contain valuable information on the distribution and habits of Indian species. On the rats and mice which cause extensive destruction to crops there are several papers by Wagle (1928), Fry (1931), and Ayyar (1931). Between 1917 and 1920 Robinson and Kloss contributed a number of papers on Burmese and Himalayan rats and on the Oriental Sciuridæ and Viverridæ. Maxwell (1928) wrote an interesting note on the home of the eastern Gorilla, while Prater (1929) gave an account of the distribution and habits of the Dugong or the Sea Cow. No account of the Indian Mammalia can be deemed to be complete without a reference to the series of interesting articles by Prater (1933–1935) on the mammals of the Indian Empire in which he deals not only with the habits and distribution of Indian mammals but also with the problems of preservation of wild life in this country.

XIV. Morphology.

This subject has attracted the attention of many workers in India from various points of view. The pure anatomist who studies the disposition of organs and systems of structures in individuals of a species, the comparative anatomist whose interest lies in a comprehensive view of these organs and structures in closely allied species and genera, and the systematist whose conception of species, genera and higher orders of grouping may be based on some noticeable anatomical peculiarities are all of the category of morphologists.

With the inclusion of Zoology as a subject in the curricula of Indian Universities, the attention of teachers and students was naturally directed to the structure of animals (in all stages of their life) available in this country for dissection and study. With text-books of Zoology of English or American origin, based on European or American types of animals, in their hands for guidance, teachers and students were soon confronted with difficulties in understanding the structures of Indian types of animals as they differed considerably in detail from those of European and American types. The need for suitable text-books on Practical Zoology dealing with Indian types of animals was keenly felt, and this feeling was voiced by Bahl in his presidential address to the Zoology section of the Indian Science Congress in 1924 on organization of zoological teaching and research in India. His suggestion for the preparation of a series of monographs on important animal types commonly available in nearly all parts of India was taken up by a committee of Indian zoologists whose initiative resulted

in the publication of the following six memoirs entitled *Indian Zoological Memoirs* under the editorship of Bahl :—

1. The Earthworm *Pheretima* by Bahl (1926, 1936).
2. The Shark *Scoliodon* by Thillayampalam (1928).
3. The Oyster *Ostrea cucullata* by Awati and Rai (1931).
4. The Apple-snail *Pila globosa* by Prashad (1932).
5. The Monascidian *Herdmania* by Das (1936).

   The Prawn *Palæmon* by Patwardhan (1937).

These memoirs embody a considerable amount of original morphological work which, in several cases, has appeared separately in zoological journals in India or abroad, and may be said to form a landmark in the progress of Indian zoological research. It would be convenient to give an account of the progress of morphology in India by dealing with the phyla and classes of the animal kingdom in some sequence, and this section would, therefore, commence with the Protozoa and end with Mammalia.

Protozoa

The principal contributions on the morphology of various forms of Protozoa are by Bhatia, Chakravarty, Chatterji, de Mello, Ghosh, Gulati, Knowles, Kofoid, Setna, and Ray. Although the greater part of the work of these authors is necessarily systematic, it includes accounts of the morphology and life-history of several species. Mention may be made of the account of the life-history of *Entamoeba histolytica* by Knowles (1927), of the volume on Ciliophora in the *Fauna of British India* series by Bhatia (1936), and of the papers by Ray and by Chakravarty (1933, 1934, 1935 and 1936) on the life-histories of various Sporozoa in Indian Millipedes. Thapar and Chaudhury (1923) have discussed the significance of the occurrence of a third contractile vacuole in *Paramoecium caudatum*. Chatterji, Das and Mitra (1930) have described the morphology of *Terachilomastix* found infecting man and (1929) the mode of multiplication of *Pentatrichomonas* and *Trichomonas* and the origin and development of their organelles. Ray (1932) described the morphology of *Balantidium sushilii* while Chakravarty (1933) dealt with the boring apparatus of *Balantidium*. The latter author (1936) gave an account of the morphology of *Balantidium depressum*. Ray and Mitra (1937) described the morphology of the flagellate *Chilomitus caviæ* from the guinea-pig. de Mello and his co-workers (1934) studied the cytology of the three morphological types of *Nyctotherus ovalis*, and the morphology and the simple schizogonic cycle of *Hæmoproteus raymundi* which is without an intracellular stage.

Porifera

From the point of view of pure morphology this group has attracted very little attention, but the papers of Annandale (1914, 1915, 1918, 1919), Kumar (1925), Dendy and Burton (1926), Burton (1928), Burton and Rao (1932), and Gist Gee (1932) on marine and freshwater sponges contain morphological details found useful in classification.

Coelenterata

This is another group of animals which has been neglected from the point of view of morphology, but in recent years it has received relatively more attention. Reference has already been made in the section on Marine Zoology to the advances made in this group (*vide*, p. 15), but attention may be directed to the following contributions :— the morphological accounts of the curious brackishwater Hydroid *Annulella gemmata* by Ritchie (1915), of *Campanulina ceylonensis* by Lloyd and Annandale (1916), of the Actiniaria of Chilka Lake by Annandale (1915) and by Carlgren (1925), of the Madras brackish-water and marine Actiniaria by Rao (1924) and Panikkar (1935, 1936), and of the study of metamorphosis of the larvæ of *Anactinia*, *Zoanthella* and *Zoanthina* into *Cerianthus*, *Sphenopus*, and *Zoanthus* respectively by Menon (1914, 1915, 1926). Special mention must, however, be made of the histological studies by Matthai (1923) on the soft parts of Astraeid corals which led him to the conclusion that the middle lamina of Anthozoa represents what may be termed 'Mesoderm' in higher animals. The same author (1926) has studied colony-formation in this group of corals resulting in his regarding the coral colony as a whole and not the separate polyps as the individual. He has also shown that colonies are formed by extra- or intra-tentacular budding only and that fission of the stomodæum never occurs.

Echinodermata

There have been very few papers on the morphology of the members of this group, but works of a systematic nature published during the period under review include short notes on the morphology of species described. Aiyar (1935), however, published an interesting account of the early development and metamorphosis of the Madras Echinoid, *Salmacis bicolor*, dealing with the external and internal structures, and showed that sexual periodicity was absent in the specie .

Annelida

Considerable amount of morphological work has been published on this group. The Polychaeta have been studied by Aiyar and his co-workers in Madras. Among their publications may be mentioned the anatomical account of *Marphysa gravelyi* by Aiyar (1933) and the descriptions of the larvæ of several families of Polychæta and of the metatrochophore of the Archiannelid, *Chœtogordius*, the development and breeding habits of *Marphysa* and *Diopatra* by Aiyar (1931, 1933), the occurrence of hermaphroditism in *Dasychone cingulata* and other Polychaetes by Aiyar and Subramaniam (1936), and the observations on the swarming habits and lunar periodicity of *Platynereis* sp. in the Madras harbour by Aiyar and Panikkar (1937).

In regard to the Hirudinea the only papers of any importance are those by Harding and Moore (1927) on the anatomy of Indian

leeches, by Bhatia (1930) on the anatomy of *Placobdella emydæ*, and by Chelladurai (1934) on the anatomy of *Hemiclepsis*.

Prashad (1919) studied the comparative anatomy of Indian Echiuroid species of *Thalassema* while Awati and Pradhan (1935) described the anatomy of the Sipunculoid worm *Dendrostoma signifer*.

Of all the groups of Annelida, the Oligochaeta have attracted the greatest attention amongst morphologists in India. Stephen on devoted many years of work to the study of aquatic and land oligochætes both from the systematic and the morphological points of view. His papers on the calciferous and prostate glands in collaboration with Prashad (1919) and Mehra (1919) recorded considerable advances in the morphology of the Oligochaetes. His monograph (1930), *Oligochaeta*, is a comprehensive piece of work embodying all that research in India on the group had made known. The nephridial system and the intestinal glands of earthworms were the subjects of intensive study by Bahl. In a series of papers (1919, 1924, 1926) he described a new type of *enteronephric* nephridial system in three species of the family Megascolecidæ in which the excretory products are discharged into the intestine instead of to the exterior as in the majority of earthworms. In 1922 he described the development of this new type of nephridia confirming Goodrich's view of the centripetal growth of Oligochæte nephridia. He (1934) also discussed the significance of this new type of nephridial system and brought forward evidence in support of the suggestion that the discharge of the excretory fluid into the alimentary system is a special adaptation for the conservation of moisture in a dry climate. The same author (1921) gave a complete account of the blood-vascular system of *Pheretima*, and in 1927 described the simplest form of conjugation in the earthworm *Eutyphoeus*. Bahl and Lal (1933) made a thorough study of the intestinal glands of the species of *Eutyphoeus* from the structural, micro-chemical, and experimental points of view and brought forward convincing evidence to prove that these glands were of the nature of a hepato-pancreas. Among other contributions to the morphology of these worms may be mentioned those by Mehra on the sexual forms of the Naidid oligochætes (1920), on the genital organs of *Stylaria* (1924), and on the relations of the atrium and prostate glands in the Microdrili (1925), and by Aiyer (1928, 1929) on the diffuse nature of sexual cells in *Aeolosoma travancorense* and on the sexual organs of the Tubificid, *Aulodrilus remex* and *A. pectinatus*.

Platyhelminthes

Although the recent development of helminthological studies in India has focussed attention on the members of this group, there have been, in the period under review, only a few papers devoted to the detailed morphology of the species known. The taxonomic studies, however, tend to lay more emphasis on the morphology of species described.

Reference to these has already been made in the section on Helminthology. The only papers on the morphology of Trematodes are those by Stewart (1914) on the anatomy of *Polystomum kachugæ*, by Sewell (1920) on the external and interal morphology of *Mesocœlium sociale*, and (1930) on the evolution of the excretory system in furcocercous cercariæ, and by Sinha (1932–1935) on the morphology and bionomics of the Trematode parasites of reptiles including those of the genus *Lissemysia*, the first representative of the Aspidogastridæ from Indian tortoises. Sewell's (1922) monograph on Indian Cercariæ deals entirely with the morphology of these larval forms. The morphology of the Cestode, *Gigantolina magna*, was described in detail by Poche (1926) who discussed its systematic position on the basis of its morphological features. Mirza (1929) studied the anatomy of *Dracunculus medinensis* and compared it with that of species of *Ascaris* and *Ichthyonema* (*Philometra*). He demonstrated in *Dracunculus* the degenerate condition of the digestive system and the absence of uterine connection with the intestine. The contributions of Faust (1927) and van Cleave (1928) to the morphology of helminths has been referred to in the section on Marine Zoology.

Chaetognatha

John (1931, 1932, 1933, 1937) has made a series of contributions on the morphology of the head of *Sagitta*, and on the distribution of *Sagitta* of the Madras coast. Lele and Gae (1936) have studied the *Sagitta* of the Bombay coast.

Mollusca

There has been considerable progress in our knowledge of the morphology of this group, perhaps more than in any other group of the animal kingdom, during the last quarter of a century. The reason for this has been explained in the section on Conchology. Complete anatomical accounts of various species of (1) marine, (2) freshwater, and (3) land molluscs have been given (1) by Moses (1924) on the Indian Chank, *Xanchus pyrum*, by Rao (1936, 1937) on the Nudibranchs, *Kalinga ornata* and *Stiliger gopalai*, and by Awati and Rai (1931) on the Oyster, *Ostrea cucullata*, (2) by Sewell (1921) on *Viviparus bengalensis*, by Rao (1923) on *Indoplanorbis exustus*, by Prashad (1925) on the Indian Apple-snail, *Pila globosa*, and by Seshaiya on the Bythinid, *Mysorella costigera* (1930), and on the Melaniids, *Paludomus tanschaurica* (1934) and *Melania* (*Radina*) *crenulata* (1935), (3) by Ghosh (1915) on the Burmese slug, *Atopos gravelyi*, by Seshaiya (1932) on the land-snail, *Rhachisellus punctatus*, and by Kretschmar, Schneider and Weber (1919, 1920, and 1925) on the snail *Cyclophorus ceylanicus*. Apart from anatomical accounts there have been numerous contributions on the morphology of various groups of molluscs, among which may be mentioned those of Annandale (1918–1925) on the fresh- and brackish-water molluscs of India and Burma, of Ghosh (1920) on the anatomy of Solenidæ, of Prashad (1918–1925) on the

anatomy of Indian Ampullariidæ and Pelecypoda, and (1928) on the structure of the mantle in the Viviparidæ, of Ortmann (1911-12) on the anatomy of bivalve molluscs and of Rao (1924, 1925) on the comparative anatomy of Viviparidæ, Succineidæ and Lymnæidæ. The morphology of Ceylonese Molluscs has been studied in detail by German workers. The contributions are chiefly those of Hoffmann (1925) on the anatomy, distribution and biology, etc. of the Vaginulid Pulmonata, of von Knorre (1925) on the shell and locomotory sense organs of chitons, of Seyffert (1931) on the anatomy of the Fissurellid *Clypidina notata* and of Riese (1931) on the nervous system of *Cypræa moneta*.

Arthropoda

In this phylum morphological studies have been confined more or less to the class Insecta, but a few papers on Crustacean morphology have also appeared in recent years. Among the latter may be mentioned the contributions of Patwardhan and Reddy. Patwardhan (1934, 1935) has contributed a series of papers on the comparative morphology of the gastric mill in the Anomura, Brachyura and Macrura adducing evidence to show the correlation between the reptantous habit and the possession of a reduced gastric mill and complex mandibles. The same author (1937) has contributed a monograph on the river prawn, *Palaemon*, for the *Indian Zoological Memoirs*. Reddy (1934, 1935) has given an account of the structure, mechanism, and development of the gastric armature in Stomatopoda and studied the variations in the gastric armature of some South Indian Decapod Crustacea.

Contributions of a monographic nature among Insects appear to be very few during the last quarter of a century, but the accounts of the anatomy of *Dysdercus cingulatus* by Pruthi (1923), of *Embia minor* by Mukerji (1927), and of the worker-ant *Dorylus* (*Alaopone*) *orientalis* by Mukherji (1933) seem to be of this type. There are, however, numerous papers on the morphology of external or internal structures of Insects by various authors. Some of these have already been referred to in the section on Entomology. Among the earliest contributions of this period are those by Awati (1914, 1915) who gave an account of the mechanism of suction in Capsid bugs, and the genitalia of the genus *Musca*. The works of Christophers (1922), Pruthi (1923–1929), George (1926–1929), and Mehta (1933) on the genitalia respectively of Diptera, Hemiptera, Coleoptera, and Lepidoptera have unravelled many knotty points on the morphology of these Insects.

The importance of the study of Insect genitalia in taxonomic work has been emphasized in recent years, but in the absence of a uniform terminology in regard to the homology of various parts in different orders of Insects much difference of opinion has arisen with respect to their origin. The gonapophyses in the male Insect have been regarded by authors: (1) as specially developed organs without any relation to the appendages, (2) as the embryonic

appendages of the last 3 segments of the abdomen, or (3) as those of the 8th and 9th segments, the latter being subdivided into two pairs. Pruthi (1924) and George (1929) working on Homoptera, and Christophers (1922) on Culicidæ have shown that the aedeagus is formed by the fusion of the paired penis lobes and that before the fusion takes place each part of the primary rudiment becomes differentiated into the paramere and the penis lobe.

The anatomy of certain species of the little known group Collembola has engaged the attention of Mukherji (1932). The same author (1926) has studied the digestive and reproductive system of the male ant, *Dorylus labiatus*. He and Mazumdar made (1935) a comparative study of the digestive system of the common ants of Calcutta. Sen (1931) studied the external morphology of the Ichneumon fly, *Xanthopimpla pedator*. Among the papers on Coleoptera may be mentioned those of Pruthi (1929) on the morphology of the larva and pupa of the Dryopid beetle, *Helichus*, of Pradhan (1937) on the morphology of the genitalia of Coccinellidæ, of Mukherji (1930) on the respiratory system of *Cybister* larvæ and of Mukherji and Bhuya (1936) on the reproductory system of certain Bruchid beetles of the genus *Bruchus*. Krishnamurti (1929) gave an account of the suctorial apparatus of the cicada, *Platypeura octoguttata*, while Presswala and George (1935) described the respiratory system and the mode of respiration in the water-bug. *Sphaeroderma rusticum*. The Orthoptera have not been neglected either. Rao (1933) studied the spermatogonial divisions in the Pyrgomorphine Acridiid, *Aularches miliaris*, and the chromosomal aberrations occurring in unirradiated grasshoppers (1934), while Kapur (1935) described the musculature and nervous supply of the genitalia of the *AK*-grasshopper and the Desert Locust. Sen (1933) studied the genitalia of the common Indian cockroach, *Periplaneta americana*. Mukerji (1935) studied the external genitalia of the Embiid, *Oligotoma*, and earlier still (1927) the morphology and bionomics of *Embia minor* with special reference to the spinning apparatus. The only paper on the morphology and biology of a Lepidopterous insect is that of Pruthi (1928) on the Hydrocampine aquatic form, *Aulacodes*.

The anatomical peculiarities of the Red pumpkin beetle and the cotton White-fly have been studied by Husain while those of the Lac-insect have been described by Negi and Misra. The studies of the morphology of the mosquito larvæ by Puri (1928) and Iyengar (1928) and of the genitalia of the genus *Musca* by Patton and Roy are also worth mentioning.

The mouth-parts and male genitalia of Mallophaga infesting N. Indian birds were studied by Qadri (1936) who found that the genitalia in *Amblycera* were of a generalized type and had undergone less modification whereas in Ischnocera they were specialized along divergent lines.

In his investigations on the wing buds in the pupa of Aphaniptera, Sharif (1935) supposed that they were completely absorbed in the adult stage, and consequently presumed that the ancestors of fleas had functional organs of flight on the metathorax which have become rudimentary in the pupa. Sen (1935) has shown that the mechanism of feeding in Ticks is associated not with the cheliceræ or the hypostome but with the stylet of the pharynx.

The studies of Plate (1916) on the rudimentary hind wings of the leaf-insect, *Phyllium pulchrifolium*, of Vogel (1921) on the anatomy of the light organs of *Luciola chinensis*, of Ahrens (1931) on the body articulation, skin, and trachea of the Termite-queen, and of Vitzthum (1931) on the eye of *Amblyomma clypeolatum*—all of the Ceylonese fauna—are of considerable interest.

Cephalochordata

The morphological work on this group by Prashad (1934) and Franz (1925) has already been referred to in the section on Marine Zoology. The latter author has studied the nervous system, sense organs, and development of various species (1925, 1931).

Urochordata

The study of Indian Tunicata by Oka (1915) has already been alluded to, but in recent years the interest in this group has been revived by Sewell (1926) and by Das (1936). The former has described the morphology of several forms of Indian Salps while the latter has devoted his attention to the structure and function of certain structures in Cynthiid monascidians. Das has shown that the test in these forms acts not only as an organ of protection and attachment for the animal but also as respiratory and sensory organs by demonstrating the occurrence of receptor organs, nerve-cells, nerve fibres, and vascular ampullæ in the test. He has also suggested a solution for the much discussed problem of carbohydrate storage in these animals, and considered it probable that in ascidians having a distinct liver the carbohydrate is stored in the form of starch while in those with no liver it is stored in the form of glycogen.

Chordata

Pisces.—A number of important papers has been published on the morphology of particular systems of organs of various fishes. The skeleton of fishes has been studied by a number of authors. Sarbahi (1933) and Dharmarajan (1936) have given detailed accounts of the skeleton of the Indian Carp, *Labeo rohita*, and the Sciaenid fish, *Otolithus ruber*, respectively. Bhimachar (1932) described the cranial osteology of *Ophicephalus striatus* and (1933-34) the comparative morphology of the skull of Indian Cat-fishes. Awati and Bal (1933-1934) studied the endoskeleton and blood-vascular system of the globe-fish, *Tetrodon oblongus*. Awati and Pinto (1937) have described the skeleton of *Harpodon nehereus*. Sen (1928) gave an account of the branchiocephalic system of blood-vessels and of the dorsal aorta of the freshwater Carp, *Labeo rohita*, while Ray and Das (1931) described the portal circulation in the Siluroid fish, *Arius*. Mitra and Ghosh

(1931) studied the internal anatomy of certain species of the families Chaudhuriidæ and Mastacembelidæ, and Rahimullah (1935) the structure and function of the pyloric caeca in Ophicephalidæ and Notopteridæ. Nair (1937) studied the changes in the internal structure of the air-bladder of *Pangasius pangasius* during growth. The morphological accounts by Karsten (1925) and Popovici (1931) of the eye of *Periophthalmus kolreuteri* and of the lateral line of bony fishes respectively are based on material collected in Ceylon. A short paper by Mookerjee (1934) on the development of the intervertebral ligament in Teleostean fishes is also of interest.

Batrachia.—There are numerous papers on the morphology of these animals published in recent years. Among the earlier papers may be mentioned those of Nicholls (1915) on the urostyle of Anura and of Bhatia and Prashad (1918) on the skull of *Rana tigrina*. The anatomy of the adhesive apparatus of the tadpoles of *Rana afghana* was described by Bhaduri (1934-1935), while the posterior lymph hearts of S. Indian Batrachia were studied by Rao (1932). The morphology of the Ranid frogs was studied by a number of authors among whom may be mentioned Ramaswami (1934, 1935) on the cranial morphology of Pelobatid Anura, Bhaduri (1932) on the urinogenital system of *Rhacophorus* and on the circulatory system of frogs and toads (1929, 1930), Rai Choudhury and Das (1929) on the malformations in *Bufo melanostictus*, Mahendra (1936) on polymely and correlated abnormalities in the muscular, skeletal and nervous systems of *Rana tigrina*, and Gnanamuthu (1933) on the anatomy of the tongue of *Rana hexadactyla*. The Engystomatid toads have similarly been studied in detail by Rao and his co-workers in Bangalore. Seshachar (1928), Rao (1930), and Ramaswami (1932) have contributed a number of papers on the skeletal and nervous systems of these toads. Devanesen (1922) gave an account of the anatomy of the Engystomatid toad *Cacopus systoma*. The little known limbless amphibians of the order Gymnophiona have been studied by various authors. The papers of Datz and Engelhardt (1925) on the skin, eyes and tentacle-apparatus of *Ichthyophis glutinosus* and of Chatterjee (1936) on the anatomy of *Uræotyphlus menoni* are among the most interesting. The series of papers on the development of the vertebral column of various Batrachians by Mookerjee (1930, 1931, 1932, 1935) added materially to our knowledge of the morphology of this group.

Reptilia.—This group has received much attention in recent years in regard to the morphology of various systems of organs of lizards, monitors, tortoises, and snakes. Amongst those who studied the morphology of lizards may be mentioned Woodland (1920) on caudal autotomy and regeneration, Hora (1923) on the adhesive apparatus on the toes of Geckoes, Mahendra (1936) on the anatomy, reproduction and development, and Bhatia and

Dayal (1933) on the arterial system of the house-gecko, *Hemidactylus flaviviridis*, Thapar (1921, 1923) and Bhattacharya (1922) on the arterial and venous systems of *Varanus*, Bahl (1937) on the detailed structure of the skull and the disposition of the cranial foramina in *Varanus*, Bhatia (1929) on the arterial and venous systems of *Uromastix*, and Gnanamuthu (1930) on the mechanism of the throat-fan in the ground-lizard, *Sitana ponticeriana*, and on the anatomy and mechanism of the tongue of *Chamaeleon calcaratus*. Mookerjee and Chatterjee (1934) Mookerjee and Mukherjee (1935) and Mookerjee (1932) have contributed a number of short papers on the skeletal morphology and development of the vertebræ in snakes and tortoises. Ray (1934, 1936) has studied the arterial and venous systems of the Indian rat-snake, *Ptyas mucosus*, while Mahendra (1936) has described the endo-skeleton of the blind-snake, *Typhlops braminus*. The epidermal sense organs of Ceylonese Agamid lizards were studied by Preiss (1922) and Eckart (1925), while the poison-apparatus of the Ceylon Cobra and Viper were studied by Wolter (1925) and Radowanowitsch (1931). The buccal glands and teeth of opisthoglyphous Ophidia were studied in detail by Sarkar (1923). Mookerjee and Das (1933) have described certain peculiar apertures in the vertebral centra of *Typhlops braminus*. Rao (1933) gave an account of the digestive tract of *Emyda vittata*.

Aves.—Bird morphology does not appear to have attracted the attention of many workers in India. Das (1924) studied the intra-renal course of the so-called portal vein in some Indian birds and concluded that it does not break up into capillaries or sinusoids in kidneys and does not form a real renal portal system. Mookerjee (1935) discussed the cause of formation of a heterocoelous vertebra in the bird. The same author has in a series of papers (1930–1935) studied the development of the vertebral column in various vertebrates and formulated a hypothesis to explain the procoelous, opisthocoelous, amphicoelous, and heterocoelous conditions of the centra.

Mammalia.—The morphology of the Lemur, *Loris lydekkerianus*, has been studied in detail by Rao, Rau, and their co-workers in S. India where the species occurs commonly. Rao (1927, 1932) dealt with the structure of the uterus and its glands, the relation of the gland cell-inclusions to secretory activity, and the structure of the ovary and the ovarian ovum. Rau and his colleagues (1928, 1930, 1931) published an important series of papers on the gall-bladder, and on the arterial, urinogenital, and skeletal systems of the same species of Lemur. Rao and Ayer (1931) also contributed to our knowledge of the anatomy of this species. Mookerjee (1933) gave an account of the external morphology of the foetus of an Indian Elephant, while Schulte (1937) described the urinogenital system of the Indian Elephant, *Elephas indicus*. The latter author found that the kidney was not divided into cortical

and medully region and was devoid of a plexus. The testes were fixed and abdominal and the sperm non-motile. Mookerjee (1932) reported on the occurrence of a so-called marsupial bone in Microchiroptera, and Ramaswami (1933) described some stages in the placentation of the bat, *Vesperugo leisteri*. The vascular and genito-urinary systems of the squirrel, *Sciurus palmatus*, were studied by Tirumalachar and Srinivasa Moorty (1930) and by Siddiqi (1935) respectively. Malhotra (1935) gave an account of the morphology and the bionomics of the house-shrew, *Crocidura caerulea*, while Ayyangar (1937) described the course and distribution of the nerves supplying levator and rhomboideus muscles, the formation of the phrenic nerve, and other anatomical details of the common ox. Das (1922) demonstrated the common occurrence of truncated thickened umbilical arteries in various species of Indian Mammals.

XV. Cytology.

Interest in the study of the Golgi apparatus and mitochondria was revived since 1917 by the publication of a series of papers on the cytoplasmic inclusions of germ cells by Gatenby. Numerous publications have appeared since then dealing with the structure and function of the Golgi and other elements in the somatic and germ cells. In India work on problems of gametogenesis only has been carried out in certain centres both in North and South India. The review of progress of cytological research in India may be dealt with under the heads, Oogenesis and Spermatogenesis.

Oogenesis.—The most commonly met with bodies of fatty or albuminous nature in the cytoplasm of growing oocytes are the Golgi bodies, mitochondria, nucleolar extrusions, and yolk. Of these, the last belongs to the category of deutoplasmic inert material, while the first two and, in some cases, the third also are now almost universally classed among independent protoplasmic bodies as they have the properties of growth and reproduction like all living organisms. Some oocytes have even a system of vacuoles containing a watery fluid.

Nucleolar Extrusions

It has been established beyond doubt that these extrusions, which very often migrate into the ooplasm, contribute directly or indirectly towards the formation of albuminous yolk. The evidence for this statement lies in the following facts: (1) the nucleolar extrusions and albuminous yolk are of the nature of protein as shown by their reactions to the common laboratory fixatives, (2) the extrusions always precede the appearance of yolk, (3) the nucleolus of the yolk-less oocytes remains inactive throughout oogenesis as in the scorpion, *Palamnœus*, whereas the nucleolus of the oocytes containing considerable quantities of yolk shoots out into the cytoplasm a large number of extrusions as in the scorpions

of the genera, *Buthus* and *Euscorpius*, (4) the extrusions, in some cases of oogenesis, form the yolk bodies directly. From the year 1924 onwards several workers in India have published results demonstrating nucleolar extrusions in eggs of various insects, crabs, prawns, scorpions, centipedes, and molluscs among Invertebrates, and in those of tortoises amongst Vertebrates. Prominent among these are Bhattacharya, Nath, and their co-workers, and Rai and Subramaniam.

Mitochondria

Judging from the solubility of mitochondria in the common fat-solvents such as acetic acid, alcohol, ether, chloroform, etc. the composition of mitochondria appears to be of lipo-proteinous nature. The relative resistance of mitochondria to fat-solvents and the progressive increase of that resistance in the course of oogenesis, and generally in histogenesis, have led to the conclusion that the mitochondria are deprived of their lipoidal constituents and give rise to yolk by a condensation of albuminous material. Between 1925 and 1934, Bhattacharya, Nath, Das, Dharamnarain, Krishna Menon and Muthuswami Iyer have demonstrated the transformation of mitochondria into albuminous yolk in the apple-snail, the crab, the frog and toad, the tortoise, and the pigeon, but the demonstration is easier in the fresh oocytes as observed by Nath and Bhatia in *Rana tigrina* and *Palæmon lamarrei*.

Golgi Apparatus

The Golgi apparatus takes various shapes and forms. It may occur in the form of a granule, a ring, a vesicle (as in eggs generally), a crescent, a dictyosome, a platelet, or a net-work, and is supposed to have an osmiophilic and an osmiophobic part, the former presumed to be lipoidal in nature and the latter to be of the nature of cytoplasm or even of a vacuole. Nath (1933) has advanced the view that the two parts are only an expression of the quantitative contents of lipoids based on the observed osmic acid and stain (Sudan III and Scharlach R) reactions, and that the time taken for the reaction is dependent on the degree of saturation of the lipoids and the previous state of oxidation. Subramaniam and Aiyar (1937) have contributed a clear analysis of the shape and structure of Golgi bodies in eggs of Invertebrates and have discussed the probable modes of origin of the Golgi network. The direct transformation of the Golgi elements into fatty yolk was first demonstrated by Nath (1924) in the centipede *Lithobius forficatus*. Working on various Invertebrate and Vertebrate animals, he and his co-workers showed that although the Golgi elements may be blackened in a short time, they do not take any stain with Sudan III and Scharlach R during oogenesis until the optimum oxidization of the lipoid is reached. Once the lipoids are converted into fats the stain reactions are positive. That fatty yolk is formed by the Golgi elements in various animals has been confirmed by several workers in India since 1928. Among these may be mentioned

Das, Bhattacharya and his co-workers, Rai, Dharamnarain, Menon, and Muthuswami Iyer, As Nath has shown, the changes in the Golgi apparatus from the youngest to the most advanced stages of the oocytes are best observed in the fresh condition. Recently Subramaniam and Aiyar (1936) have made the interesting suggestion that the Golgi bodies produce certain enzymes which, acting on materials derived from cytoplasm and its inclusions, give rise to fat, fatty yolk, and yolk. Subramaniam (1937) has also suggested that in addition to synthesizing yolk, fat, lipoids, etc. in specialized cells, the enzymes may be concerned in the metabolism of ordinary cells. Rao (1932) observed in the S. Indian Lemur, *Loris lydekkerianus*, that both the Golgi bodies and mitochondria assist in the formation of secretions in the uterine glands. Opinion in regard to the great diversity of results obtained by various workers on the same species of animal seems to be divided. Subramaniam and Aiyar (1936) have expressed the view that seasonal and geographical variations in the environment are the cause of this diversity, while Nath holds that variation in the technique of fixation is responsible for the diversity. The nutritive function of the Golgi bodies in the oögenesis of Vertebrates and Invertebrates has been demonstrated by Bhattacharya and Nath and their co-workers. In the former they have shown an infiltration of the Golgi elements of the accessory cells in the egg through its surrounding membranes, and in the latter the Golgi elements of nurse cells migrate intact along the nutritive roots and mingle with the Golgi elements of the oöcytes. Recently Subramaniam (1937) had made the suggestion that some of the Golgi elements in Protozoa may become modified as the contractile vacuole, parabasal or stigma in some species.

Vacuome

Cytologists in India have controverted Parat's view that the watery vacuoles which stain with neutral red are the homologue of the classical lipoidal Golgi apparatus. Bhattacharya and Nath and their co-workers (1929, 1930, 1931) have demonstrated the existence of the vacuome and Golgi apparatus as independent cell-components in the eggs of the earthworm, *Lumbricus*, of the pigeon, of the common frog, *Rana tigrina*, and of various Teleostean fishes. In the eggs of the two latter, the mitochondria, Golgi elements, and the vacuoles are clearly seen in *intra vitam* preparations without the use of neutral red or osmic acid.

Spermatogenesis.—Very little work appears to have been done in India on this subject. Nath (1932) has clearly elucidated the cytoplasmic structures of the curious spermatozoan of the Crab *Paratelphusa spinigera* and shown that in spite of its bizarre appearance the crab spermatozoan is a typical form. He has also produced evidence to prove that at the time of fertilization when the unusual form of the sperm changes into that of a typical one the penetration of the sperm nucleus into the egg is assisted by the explosion of the

mitochondrial vesicle. Owing to the peculiar form and position of the acrosome in certain sperms, the function of the acrosome cannot be considered as that of a perforatorium as it was a few years ago. Muthuswamy Iyer (1933) has obtained similar results in *P. hydrodromus* except that the changes in the nucleus of the spermatid show minor variations. Rao (1933) studied the behaviour of chromosomes in the male germ cells of the Acridiid *Orthacris*. Nath (1937) has described, in the prawn, *Palæmon lamarrei*, the curious structure of the sperm. The explosive mechanism appears to be of such great importance that the entire cytoplasm of the spermatid with all its mitochondrial and Golgi material is used up in its formation, and the acrosome is altogether absent. Seshachar (1936, 1937) has studied the spermatogenesis of *Ichthyophis glutinosus*.

The occurrence of Golgi apparatus in Protozoa appears to be disputed except in the Sporozoa, and the so-called Golgi apparatus of these organisms does not answer to the definition of the Golgi apparatus in other animals. Subramanium (1937) has recently attempted a critical definition of the Golgi apparatus in general and of that of the Protozoa in particular.

XVI. Bibliography.[1]

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PROGRESS OF FORESTRY IN INDIA DURING THE PAST TWENTY-FIVE YEARS.

By

[illegible]
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CONTENTS.

I. INTRODUCTION.

In Volume III of his valuable work on the 'Forests of India', Professor E. P. Stebbing gives a fairly detailed account of the progress of conservancy and the development of research in forestry for the period 1901–1925. He points out that before 1900, the important works of settling, demarcating, and surveying the state forests, and bringing their protection on to a sound footing with usually conservative exploitation in the more accessible parts, occupied most of the time of the professional staff. The next few years may be viewed as a period of transition when ideas were changing and a more truly scientific attitude towards forestry was materializing. The most obvious indication of this was the initiation of the Forest Research Institute at Dehra Dun in 1906, and the opening of its buildings in 1914 which thus ushered in the period under review. The progress made during this term of 25 years in all branches of forestry has been far greater than that

seen by any previous quarter-century. This fact will become apparent from the later sections of this article, which will deal primarily with the silvicultural and management aspects of forestry as a branch of applied botany, and treat only briefly of the industrial or utilization aspects though these are equally important for the balanced progress of forestry and have seen equally far reaching developments. That Indian forestry has a long history prior to 1912 is illustrated by the fact that the 'Indian Forester' celebrated its sixtieth year in 1935 having been started by Schlich in 1875.

II. Forest Education.

From the time the Forest College at Coopers Hill was shifted to Oxford in 1905, probationers to the Indian Forest Service were trained at Oxford, or (from 1910) at Cambridge or Edinburgh, each University providing a regular course in Forestry. In the few years preceding the war, a University Honours degree in Science was a necessary qualification for probationers who then had to go through a further 2-3 year period of professional training and the standard for recruits was at that time a high one. Recruitment, except by promotion, ceased during the Great War after which the academic requirements were somewhat reduced for obvious reasons for the next year or two, but soon returned to their former high level. Owing mainly to over-recruitment at this period, very few appointments have been made during the last 10 years. The service thus includes many men well qualified to undertake scientific research work when opportunities are given.

Senior Training Courses at the Forest Research Institute

With the opening of the Forest Research Institute arrangements were made for professional training in India beyond what could be given in the long established 2-year Ranger's course, and in 1912 a separate course was started—the recruits having a much higher general standard of education than was required for Rangers, in fact most have good Indian University degrees. This course was continued until the long discussed suggestions for training for the Indian Forest Service in India bore fruit in 1928 with the appointment of a Professor of Forestry and the opening of a new class. It is generally admitted that India now has forests which have been long enough under systematic management to provide the necessary practical illustrations required for teaching purposes, and that whereas till recently suitable training was only possible in Central and Western Europe, a relatively short period spent there will now suffice if following on the course of training given in India. Unfortunately owing to the stopping of recruitment, the class had to close down after only 5 years' existence, but it is likely to be reopened in the near future. The Provincial Service Course, which had been in existence since 1906, was closed down in 1928, as it was no longer required under the new conditions. It may be mentioned

that the leading position held by India in scientific tropical forestry is recognized in all parts of the world and that foresters from other tropical countries are frequent visitors to India.

Subordinate Courses

In the subordinate service the educational standard has steadily improved in all ranks so that there are now available in most provinces Rangers and Foresters competent not only to take charge of forest ranges and divisional operations such as markings, tending, roads and buildings, etc., but also to make and record the detailed observations called for in modern research work. The Ranger College at Dehra Dun with sixty years' history behind it continues to meet the requirements of North India, whilst since 1912, the Madras Forest College at Coimbatore has arranged for the training of Rangers for South India and Bihar.

III. Organization of Research.

Forest Research Institute, Dehra Dun

It was not long after the Research Institute was opened in 1914 that it was found inadequate to meet the demands made on it, the boom conditions and general optimism prevailing just after the Great War being an important contributory factor. A new Institute was conceived on an ambitious scale and completed in 1927 at a capital cost of approximately Rs. 1 crore. The Forest Research Institute as now constituted consists of 5 branches, Silviculture, Utilization, Botany, Entomology and Chemistry, under the direction of the President who has for some years now also been the Inspector General of Forests. The Silvicultural Branch has come to differ considerably from the other four branches in that experience has taught that only relatively restricted portions of the field to be covered can be centralized. Expansion of staff and work has accordingly been mainly in the provinces, the Central Silviculturist acting primarily in an advisory capacity. In all the other branches, centralization offers many advantages and is indeed often essential, so expansion has taken place mainly at the Institute even when local activities have also increased ; this is most markedly the case with Utilization which calls for expensive machinery and highly qualified specialists.

Officers (except for Chemistry) are deputed from the Provincial cadres, for a period of years, to hold charge of Branches so that close touch may be maintained with practical forestry and the views of all the provinces have opportunities of influencing the direction of research—this is especially the case for the Silvicultural Branch.

Programmes of research are drawn up in consultation with Provinces, the aim being to concentrate attention on the problems considered to be most important by the administrative and Executive staffs of all parts of the country.

The Institute has arranged a series of Exhibition Halls illustrating the various activities of Indian forestry which a recent

visiting expert on Museums, etc., classed as among the finest and best maintained in the country. It also has accumulated a collection of nearly 8,000 photographs dealing with Indian forests and forestry. The herbarium, insect collections and libraries are also of outstanding value.

(a) *Silvicultural Research.*

During the 5 years preceding 1915, R. S. Troup was Silviculturist and laid the foundations of systematic research in this field. Two outstanding pieces of work were the compilation of all the available silvicultural information for each important species in his '*Silviculture of Indian Forest Trees*', and the laying out of a considerable number of permanent plots for the collection of growth statistics for the chief species which occur in more or less even-aged crops. The book, published in 1921-22, remains the standard reference work on the subject, and many of the plots have completed 25 years with quinquennial measurements and contribute largely to the statistical data required for calculating the permissible sustained outturn of our forests. At that time, there were no silvicultural research appointments in the provinces and Troup attempted to cover the whole of India. E. Marsden succeeded Troup and whilst continuing the work started by him, attempted to systematize and compile the large amount of statistical data collected over a long period of years by divisional officers : unfortunately most of these data are unreliable and the methods of collection so varying that compilation cannot yield satisfactory results.

Meanwhile, provinces realized the need of silvicultural research to solve the practical problems with which they were faced, mainly in connection with regeneration work ; they also realized that it was impossible for a single officer at the Forest Research Institute to take up all these problems and that the appointment of provincial Silviculturists was essential. So, beginning with the United Provinces in 1918 and Bengal and Madras in 1919 (Burma was actually the first in 1916) one province after another appointed a whole time Silvicultural Research Officer, till now there is a Silvicultural division or its equivalent in all provinces except in Bombay and the newly constituted province of Sind. As will be seen later, several of the larger provinces have also created a new administrative post for Working Plans and Research, the United Provinces in 1920 being the first to do so.

Howard, who had already been closely connected with the work in progress and had published a *Code for the Collection and Tabulation of Statistical data,* succeeded Marsden in 1919. He followed up this line of work, and during his term of office compiled yield tables for even-aged crops of *Shorea robusta, Pinus longifolia* and *Cedrus deodara,* shewing the standing volume and intermediate yields from thinnings at each decade of age up to maturity on sites of standardized quality classes. The compilation of these tables was

rendered possible by the measurements accumulated from the plots laid out by Troup and Marsden, supplemented by others laid out by Howard and his now well trained staff, and provides an important landmark in Indian forestry. Howard also continued small scale experiments at Dehra Dun on plantation technique, as had his predecessors.

The present writer succeeded Howard in 1926 and held the post for 11 years. The statistical work was by now thoroughly standardized and could mostly be carried on by a duly qualified assistant, as was most efficiently done for much of the time by I. D. Mahendra. Yield tables for *Pinus excelsa* were prepared, and a new set of tables for deodar was compiled to bring out the differences in average diameter, etc., of crops grown to the same age under different intensities of thinning; these 'multiple yield tables' were the first of their kind produced in India. Though the available data were admittedly very inadequate, a provisional yield table for *Quercus incana*, which presents a problem unknown in Western forestry of a tree whose age cannot be determined owing to the absence of distinguishable annual rings, was also prepared, as the need was greatly felt for regulating the yield in several hill forests where this oak is an important source of fuel.

Volume tables have also been prepared for a number of commercially important species giving the average volumes of timber over a fixed standard size and suitable for conversion in trees of different diameters and heights, or on sites of different quality; this continued Howard's work on similar lines for *Shorea*, *Pinus longifolia* and *Cedrus*.

The effective standardization of most of this statistical work—not that standardization has ever been allowed to become stagnation, for new and improved methods have been constantly under investigation—permitted the Central Silviculturist to devote more time to the experimental work connected with regeneration problems, especially with natural regeneration. In this field, essentially a branch of forest ecology, no satisfactory research technique had been developed and the provincial Silviculturists, with their limited facilities and cut off from other research workers, were hardly in a position to supply a remedy. To provide a basis on which to build further and to render available to local research workers experience so far acquired in dealing with the varied problems requiring study, an '*Experimental Manual*' was published in 1931, being a companion volume to a new '*Statistical Code*' published at the same time. In the experimental work, as in the statistical, it was agreed that standardized methods were very helpful so long as they left ample elasticity for developments met with in individual problems. The proposals were accordingly mostly discussed at the Silvicultural Conferences to be described later, so that the *Manual* for the most part deals with an agreed procedure, with suggestions for the less developed lines of investiga-

tion. Representative problems will be discussed later (*vide infra*, p. 443). A further consequence of the standardization of methods and the decentralization of most forest experimental work, has been that the Central Silviculturist has been able to devote more of his time to touring with the Provincial Silviculturists and discussing problems and technique with them on the spot. This has undoubtedly been of the greatest value to all parties and raised the general standard of work particularly in the less advanced provinces and in the case of newly appointed and inexperienced officers. The same changes have also rendered possible the organization of systematic investigations on important problems concerning several provinces, examples being the regeneration of 'sal' (*Shorea robusta*), the management of bamboo, and the importance of source of seed for teak plantations; field parties from the Research Institute have been sent to assist provincial Silviculturists with some of this work and reports published (*Indian Forest Records*).

Provincial Silviculturists have regular research programmes drawn up periodically, every 3 to 5 years, usually in conference, by the provincial staff, the Central Silviculturist being usually given an opportunity of making suggestions. To provincial Silviculturists is due a large proportion of the recent improvements in research methods as it is they to whom it falls to try out proposals on the practical scale, with the resultant opportunities for meeting practical difficulties and making further advances. Such contributions have come particularly from the United Provinces, Madras, Bengal and the Punjab, which provinces have tended to take the lead in the matter.

The interest of divisional officers in experimental work is kept up not only by the Silviculturists' keeping them informed of the progress of all investigations maintained in their divisions, but also by leaving to them the carrying out and maintenance of such additional experiments, mainly of local interest, which the Silviculturist has not time to take up. There is however an important change from the old unsystematic methods in that the records have to be maintained on the standard lines and the Silviculturist has a watching brief to ensure continuity and proper maintenance and records.

Recent years have also seen the application of statistical methods to an ever widening field of experimental results, and the two sections of the Silvicultural branch of the Forest Research Institute now overlap considerably whereas formerly they tended to be quite separate. In this direction also, the Forest Research Institute is much more favourably situated than the local Silviculturist and is expected to provide a lead.

That research technique in forestry has made great progress of recent years is shewn by the fact that after visiting all the chief Forest Research Institutions of Central and Western Europe in 1931, the present writer found that though some of their older

experiments were providing very interesting results which most of our own have not yet had time to equal, they had extremely little to teach us in this direction as regards silviculture. Only in the study of forest soils and their reactions on tree growth and regeneration could it be said that we were in any way behind them, whilst in other directions we could certainly claim to have out-distanced them.

Another recently completed task which has involved a great deal of work has been the preparation of a preliminary systematic survey and description of the main types of forest occurring in India, the results having been published in 1936. The need of such a compilation for reference purposes had long been felt, and though the information available was very unequal for different parts of the country and very incomplete in many respects, it was believed that—as with Troup's *Silviculture of Indian Trees*—the first requirement was for a record of what is known, so that the necessary corrections can be made and the gaps filled by those interested.

The collection in accessible form of all silvicultural information whether published or collected on tours has always been an important activity of the Silvicultural Branch both at Dehra Dun and in provinces. At first this information was ledgered under the species name and Troup's monumental work was to all intents and purposes a compilation of the specific ledger files as they existed at the end of his term of office. Subsequently, whilst maintaining these specific files, more attention was paid to a parallel set of subject files classified on a scheme worked out by Howard. The compilation of these subject files into a complementary volume to Troup's book has recently been undertaken and is in the press as part of a *Manual of Indian Silviculture* by Sir Gerald Trevor and the present writer.

One of the most important activities of the Silvicultural Branch at the Forest Research Institute has been the organization of conferences at which important problems are discussed and lines of investigation decided on.

The first of these conferences was held in 1918 and was chiefly concerned with standardizing the methods of collecting statistical data for crop increment, the classification of thinnings and the principles of working plan control (the function of which is to ensure that the prescriptions laid down in management plans for whole forests are in actual practice carried out). The recommendations were accepted in all essentials by the Board of Forestry meeting in the following year.

The second conference was held in 1922. It dealt with developments on the lines of work just referred to, and also considered the standardization of technical terms, records of plantation work, etc., but perhaps the most important discussion settled the relations between the central and local Silviculturists. It was agreed that practically all compilation work was best centralized at the Forest

Research Institute especially that involved in the crop increment sample plots. On the other hand, the field work both for these growth plots and for regeneration and similar investigations could only be carried out satisfactorily by the local Silviculturists, the Central Silviculturist acting in an advisory and a liaison capacity, and inspecting as many of the plots as possible with the local officers. Copies of all essential records were to be supplied to the Central Silviculturist to enable him to make suggestions on them when occasion arose, and to keep him closely in touch with all developments. Provincial Silviculturists were to visit Dehra Dun as frequently as convenient.

The 3rd conference in 1929 was planned on a more ambitious scale and was attended by 36 officers including all those employed exclusively on silvicultural research. Once again, developments in subjects discussed by previous conferences were dealt with and various new items were taken up. Among the latter may be mentioned the methods of experimental research, the importance of origin of the seed used in plantations, the regeneration of tropical evergreen forests (which was producing a crop of difficult problems), the problem of the pure teak plantation (against which many objections had been urged), forest grazing, thinning research, and the selection of representative areas of forest and special individual trees for permanent preservation for the use and enjoyment of future generations of foresters and the general public. Action was subsequently taken by the Central and Local Governments on all the resolutions passed by this conference.

The 4th and most recent conference took place in 1934 and followed similar lines. Good progress was reported on the recommendations of the previous conference, and decisions reached on further developments of the several items it dealt with. New subjects considered included the artificial regeneration of selection (irregular or uneven-aged) forest which presents many difficulties, research methods for mixtures in plantations, and the technique of teak plantation work.

This section dealing with silvicultural research may be summarized to the effect that the period under review has seen the development from a single research officer for the whole of India working at a newly constituted Research Institute, to an elaborate organization centering on one of the finest Forest Research Institutes of the world, with a Silvicultural Branch consisting of a Central Silviculturist and a trained staff of about 20 men acting in closest co-operation with a Silviculturist in each province, each with his own staff. Statistical computations, compilation work, co-ordination and general advisory functions are undertaken by the Central Silviculturist, whilst the all important field work and matters primarily of provincial interest are dealt with by the Provincial Silviculturists. The number of statistical plots now maintained

(including Burma) is over 1,500 and of experimental plots, about 500, giving some idea of the extent of the work in hand.

(b) *Forest Botany.*

Forest Floras

Botanical work at the Forest Research Institute has been mostly systematic or mycological, though R. S. Hole carried through some most valuable studies on soil factors influencing the natural regeneration of *Shorea robusta* at the beginning of the period. The great progress made in systematic work is illustrated by the fact that forest floras are now available for practically every province, whereas 25 years ago we only had Brandis' *Indian Trees*, Gamble's *Manual of Indian Timbers* and a few usually very incomplete local lists. Though most of these floras were produced by officers working in the provinces, free use has been made of the important herbarium and library of the Forest Research Institute.

Mycology

In the mycological field, many important parasitic and saprophytic fungi have been studied, the latest work being a survey by K. Bagchee of the *Peridermium* spp. infecting and often destructive to the Himalayan conifers. The serious disease of the sandalwood tree known as spike disease has also been the subject of investigation by many workers.

(c) *Forest Entomology.*

This subject is dealt with more appropriately in another chapter and it must suffice here to mention the large amount of work done on the more serious pests of our timber trees notably *Hoplocerambyx* on *Shorea*, and *Xyleutes* on teak (bee-hole borer), and many defoliators, and on the insect vectors of the spike disease of sandal.

(d) *Forest Chemistry.*

This field also need not be described at length here. Investigations have been concerned mainly with three branches of the science, *viz.*, wood preservatives, minor forest products such as drugs, essential oils, etc., and soils. Much work has also been done in connection with paper making.

(e) *Forest Utilization.*

The industrial aspect of forestry has naturally occupied a big proportion of the funds and staff available for forest research and the Utilization Branch of the Forest Research Institute is by far the largest branch in buildings, staff and budget appropriations, though as already noted, this is partly ascribable to centralization for all India. There are also Utilization Officers in several provinces though their function is mainly marketing rather than research. There are research workers at the Research Institute dealing

severally with Paper-making, Wood Preservation, Seasoning, Timber Testing, Woodworking (including veneering, etc.), Wood Technology and Minor Forest Products, and from small beginnings in the years immediately preceding the Great War, a big organization has been built up the extent of which can only be realized by a visit to the Institute. R. S. Pearson who was Economist from 1909 to 1925 was largely responsible for the satisfactory development which has continued steadily up to the present time. Important advances have been made in all sections of the work among which may be specially mentioned the use of bamboo for paper pulp, the discovery of cheap new timber preservatives, marked improvements and cheapening of seasoning operations, etc.

IV. Research on Regeneration Problems.

(*a*) *General.*

Prior to the period under review, the general tendency was to apply European methods to Indian forests in the expectation, or at least hope, that they would prove successful even under the very different climatic and other conditions. Occasionally, as for *Pinus longifolia* in the Himalayas and for coppice working of many broad-leaved species in the plains, expectations were realized, but as time passed, it became evident that success was often not being obtained, notably with many of the most important teak and *sal* bearing forests. Many experiments had been and were being laid out all over the country, but without system and often without realization of the requirements of such investigations. The usual history was for the experiment to be dropped when the officer originally responsible for it went on leave or was transferred, leaving the investigation uncompleted because a number of years is almost always necessary for any conclusive results. Even where such experiments were continued longer, the records were usually so inadequate that initial conditions and details of treatment could not be guaranteed, and so much uncertainty remained as to deprive the end result of most of its potential value. It has been mentioned that Hole took up the problem of the common failure to obtain regeneration of *sal* (*Shorea robusta*), and demonstrated the important part played by the toxic action of a soil cover of dead leaves and the corrective effect of burning and soil working. This marked the beginning of the change over to an ecological approach to such regeneration problems, which has been a marked feature of recent years, and is well illustrated by the report of the co-operative investigation into the regeneration and management of *sal* published in 1933. It is now realized that many of our most important timber producing forests, including much of our teak and *sal* bearing forests, are not the climax vegetation type, and the maintenance of their commercial productivity depends on keeping them in the appropriate preclimax stage.

Closely connected is the much discussed problem of the relative merits of the pure (single species) plantation or forest, and a mixture of species. After a long period during which plantations were very generally made of a single valuable species, e.g., teak, and tending operations in natural forest aimed at raising the proportion of the favoured species even to 100%, there has been a marked swing of opinion in favour of mixtures, except in the case of naturally gregarious species such as *Shorea robusta*, *Pinus longifolia*, *Cedrus deodara*, etc. Systematic investigation of species mixtures involves a series of technical difficulties mainly connected with the specific variation of rates of growth with time, the varying reactions to the competition for light and space (above and below ground) of neighbouring plants, and the inevitable reduction in number of stems per unit of area as they grow in size. Such investigations have been initiated in the last few years in several centres, notably in Bengal, and should yield most useful and instructive information in the not too distant future.

(*b*) *Natural Regeneration.*

Teak and *sal* besides being our most important species, provide the best examples of the progress made in recent years towards the understanding of the problems involved in natural regeneration. With both species it had become apparent that whilst the efficient general protection of the forests had resulted in a very great improvement in the density of stocking and the quality of the trees, regeneration was often markedly less satisfactory where the protection had been most effective. With *sal*, regeneration had come to a full stop in many of the finest forests of Bengal, Assam and the United Provinces, though the period of protection had resulted in the establishment of large quantities of young stock which happened to be just in the right condition to benefit from it. It was realized that the most important factor in play was fire protection, and fierce controversy raged especially with reference to teak in Burma, on the relative merits of burning and protecting. Foresters were thus awakening to the significance of the phenomena we now term succession and retrogression, and this was happening from general observations rather than research *ad hoc*.

'Sal'

The failure with *sal* was so signal in Bengal that experiments were begun from about 1912 to raise this species in plantations, experiments which were destined to lead to a tremendous development of artificial regeneration to be described later. In Assam, the chief line followed was to get the forests back to their original condition in which they would burn, and replace the evergreen undergrowth which had become established with protection by the thin grass which was there before and in which *sal* regeneration can take place; this procedure, consistently advocated by Milroy, has finally been adopted, with

some additions aiming at speeding up the rate of establishment of the seedlings, as the basis of management in some of the Assam forests, and has assisted in the solving of parallel problems elsewhere. In the United Provinces, the solution of the *sal* regeneration problem became one of the most important forest matters as continuation of fellings in several of the best forests was contingent on obtaining adequate regeneration. The outcome was one of the most extensive and systematic investigations in the annals of Indian forestry, if not in forestry generally, which was carried on under a series of officers from 1919 to the present date. It can now be said that the problem is in a very fair way towards a satisfactory conclusion and that the work has made a major contribution to the development of the special research technique necessary in forestry owing to the large size of the unit dealt with, the long periods of time involved, and the complications due to a series of biotic factors. As so often happens, a number of factors are involved which must all be favourably controlled at the right points in time, if success is to be attained : suitable top canopy conditions (light intensity), suitable ground cover conditions (involving burning and shrub cutting), and protection from browsing by game, must all be assured.

Teak

With teak, which unlike *sal* usually occurs only in moderate to small proportions in mixed crops, it cannot be claimed that so much has been accomplished, but it is established that in many tracts where teak occurs, its maintenance through natural regeneration is dependent on annual or periodic fires which check or prevent progression to a denser, darker and damper stage of the natural succession. To what extent burning is harmful or helpful once the sapling stage is passed has not yet been quantitatively determined and difference of opinion persists even as to its qualitative effect. The fact that teak is exceptionally easy to raise artificially has resulted in a tendency to create plantations to make up for any deficiency in natural regeneration, though the reaction of the last few years against plantation work in Burma must be mentioned.

Conifers

Mention must also be made of progress in natural regeneration in the coniferous forests of the hills. Increased intensity of working of the last 2-3 decades has drawn attention to the big difference between taking advantage of natural regeneration which has established itself more or less spontaneously, and completely regenerating a given area in a given time. Progress has been particularly marked with deodar in the Punjab and there are also areas where good mixed regeneration of silver fir, spruce and blue pine has been obtained, notably by Trevor, as the result of systematic operations to that end. Though many experiments are in progress we still cannot however say we know how to regenerate many of our over-mature spruce and silver fir forests as a practical proposition.

(c) *Artificial regeneration.*

The expansion of plantation work has been one of the most marked developments of recent years. We have of course plenty of examples of most successful plantations from as long ago as 80 years or more, conspicuous among them being the famous Conolly teak plantations at Nilambur in Madras, but in comparison with the total acreage under forest management these were mostly very small affairs. Only in Burma could such plantation work be said to have held an established place in general forest management, apart from special afforestation schemes like that of the irrigated plantations of the Punjab (Changa Manga was begun in 1866). The failure of natural regeneration of *sal* in Bengal provided one of the chief incentives to attempt artificial sowings, and from small beginnings 1911–15, methods were very rapidly developed and within a decade had become the standard method on the divisional scale throughout the Duars. The stimulus thus given to plantation work spread to the miscellaneous forests of the plains where *Chickrassia*, *Gmelina*, *Terminalia myriocarpa*, etc., were sown, to the hills with *Alnus*, *Cryptomeria*, *Michelia*, etc., and to S. Bengal where the old plantations (begun in 1877) were restarted and extended with other species with marked success.

Whilst local initiative in other provinces played a significant part, the success of plantation work in Bengal was certainly associated with a general increase in interest in plantation work throughout the country, and it happened to fit in well with the more intensive working called for by the modern working plans being introduced about the same time. The United Provinces in particular owe much to Bengal for the remarkable development of plantation work beginning with its application to restocking of failures in coppice coupes in Gorakhpur in 1921.

Nilambur division provides a good example of plantation work which has continued steadily over a long period of years, recent developments tending towards larger scale work with renewed attention to site factors and suitability of the soil to teak. The general expansion of work in Madras has shown itself in the opening of new centres among which Mt. Stuart (from about 1919) is among the most noteworthy. Travancore also has an excellent series of teak plantations on the Nilambur model.

'Rab' Method

Recent years have seen the development of a special type of plantation work in Bombay and its spread to other provinces. This is now known as the 'Rab' method and is borrowed from the agricultural practice of burning leaves and brushwood on the fields, especially those to be used as rice nurseries. After timber fellings have been done over an area of forest, the debris is collected in places selected as most suitable and burnt there. Seed (chiefly teak) is sown on these burnt patches or *rabs* and the seedlings after a few years' weeding

and tending merge with the coppice and seedling regrowth over the rest of the area, the growing stock being thus enriched by the addition of well grown groups of the most valuable species. These *rabs* may amount only to one or two patches 30′×30′ per acre in poor forest with little material to burn, or may extend to the greater part of the felled area (Kanara), but the distinguishing feature is that no attempt is made to convert the forest into a uniform plantation.

Mention must also be made of the steady development of the irrigated plantations of the Punjab which are an important factor in the great canal colonies. Large areas have been brought under forest in several centres and great progress has been made in the whole technique of raising and managing these plantations. Intensive studies on modern lines with replicated plots, etc., have been made on a wide range of problems such as effect of depth and frequency of irrigation, spacing of plants, commencement, intensity, and frequency of thinning, effect of excluding grass, etc. Sind is now starting similar plantations.

'Taungya' Method

A most important work has been the application of the 'taungya' method. The term is derived from Burma where the practice is of long standing, and it implies the raising of forest crops in conjunction with agricultural crops. This is unquestionably one of the most significant developments in forestry, above all in tropical forestry, and has resulted in the adoption of the ancient terribly destructive and wasteful practice of shifting cultivation to the establishment of highly productive plantations in place of forest with only a small proportion of saleable timber. Its potentialities are still only very partially realized owing to our regrettable lack of detailed knowledge of the site requirements of most of our tree species and to our lack of experience in the manifold aspects of plantation management over extensive areas. Essentially, this 'taungya' procedure consists in working out all the saleable material on a compact block of land, usually from 30–200 acres, and clear felling the rest of the growth. After giving it some weeks or months to dry out, the debris is burnt broadcast and the area sown to agricultural crops, species and methods varying with locality. This work is often done by more or less primitive peoples accustomed or easily adapting themselves to the prevalent conditions. In the same season, or sometimes in the second year, forest tree seeds are sown in lines (6′–15′ apart) or at fixed intervals (usually 6′×6′) among the field crops, and the cultivators tend the tree seedlings with their own crop. Usually there is only partial field cultivation in the second year, the cultivators continuing to tend the young trees, and usually from the third year the tree crop is left in full possession of the ground, though in some localities, e.g., in Gorakhpur and the Central Provinces, cultivation may continue for 5 years or even longer. The great advantages of

the method lie in the better growth obtained with the fully cultivated and well weeded ground and in the great reduction in costs, plantations being otherwise very expensive and only offering prospects of returns after many years : at the same time, more land often with rich soil, is rendered available to cultivation without reduction of the forest area. 'Taungya' having originated in Burma, spread early to India on a small scale, but it was in the Bengal *sal* plantations that it became firmly established, thence to spread widely and rapidly so that in the United Provinces, with many modifications to suit local conditions, from a small beginning in 1921, it has now become the standard practice on a large scale in many divisions. A recent interesting development has been its application to relatively inferior forests where forest grazing is important and mixed line sowings are raised including both timber trees and trees providing good leaf fodder. 'Taungya' methods are in vogue on a smaller scale in Bihar, Orissa and Assam, but so far have not proved very suitable to Punjab plains conditions.

In the Central Provinces, Berar provides an interesting example of very successful 'taungya' with *Acacia arabica* on black cotton soil, land for cultivation being at a high premium and the soil under a tree crop being far more productive than adjoining village land long under cropping. There has also been a considerable expansion of this class of work under the name of 'agrisilviculture' in various parts of the province though there is still room for improvement in the standard of work. 'Taungya' is not so general in South India and has not been a success at Nilambur, but the method has been applied in many places including Coorg, Cochin and Travancore.

With this extension of plantation work, the importance of the source of the seed has been recognized, analogy with European experience being justified in this case. Small plantations raised with seed of *Pinus longifolia* from parents with different intensities of spiral grain, a serious defect in timber, started in 1916, demonstrated clearly that this defect is liable to be transmitted through the seed.

In 1931, a co-operative investigation was initiated in eight provinces and States into the best source of teak seed for the different localities, and it is already clear that there are marked and heritable differences between what may, for the present, be termed geographical races. Similar work is in progress on a smaller scale for many other species at the Forest Research Institute and in the provinces, as well as for strains of *Pinus longifolia* of high resin yielding capacity, for races of *Schleichera*, *Butea*, etc., of different value for lac cultivation, and for strains of *Santalum* resistant to spike disease.

Among the many other lines of work which have been taken up systematically in recent years, most of which have yielded at least provisional results of value, may be mentioned : seed storage

under various conditions, the use of root and shoot pruned seedlings ('stumps') in plantation work, and quantitative studies of the effect of varying details of planting methods, size of stock, date of planting and the intensity of weeding and soil working.

V. Tending, etc.

The earlier management of our forests very usually included what were termed 'improvement feelings', the prescribed object being to remove badly grown and inferior trees wherever they were harming more promising material. There is no question that these operations combined with systematic climber cutting brought about a very marked improvement in the growing stock of our forests. The past 25 years have seen the recognition and spread of the belief—and its translation into practice—that this did not go far enough, especially in dense young crops where a good deal more often including quite good stems, must be removed to give optimum growth and concentrate it on the best stems which can thus reach saleable dimensions more quickly. Much attention has been devoted to this subject of 'thinning' both by divisions and those responsible for research work. Comparative study of different thinning methods bristles with difficulties and calls for a high standard of technique and uniformity of treatment. It has only been really systematically taken up in the last few years and a long period must elapse before conclusive results will be available, but at least it can be said that India has faced the problem and made as good a start on it as any other country. Meanwhile, we have a standard descriptive classification of thinnings, and the yield tables for several of our chief species further provide a quantitive standard for reference.

A new line of investigation recently taken up is the study of the relative advantages on growth and quality of timber, of pruning the lower branches in plantations as compared with leaving them to fall naturally.

VI. Protection.

The importance of forest fires and browsing in relation to regeneration has already been mentioned with reference to *sal* and teak.

Fires

After a period of attempted complete protection against fire in all types of forest, the period under review has seen a marked reaction which many are inclined to view as a swing of the pendulum too far in the opposite direction. Whilst it is now well established that for certain objects in certain types of forest, burning is helpful from the point of view of silviculture and management, it is questionable whether the

throwing open once more to burning of other types of forest is not definitely harmful. There is, however, in theory if not always in practice, a fundamentally important difference between what happened in fire-protection times when the forests got burnt, usually in the middle of the hot weather, by intentional firing by villagers or by chance spread of accidental fires, and the modern practice of 'controlled burning' under which the burning is done in a way and at a season specially selected by the forest officer as the most suitable for the objects in view. This is most generally as quiet and cool a fire as possible run through the forest as soon as it is dry enough to burn (hence the term 'early burning'), but may sometimes be intentionally later and hotter as when it is desired to kill back an evergreen undergrowth to facilitate regeneration. Controlled burning has also been widely introduced as the lesser evil in the exceptionally inflammable coniferous forests (and sometimes also in grassy plantations), where the fire risk is rated so high that the risk of a really destructive fire fed by the debris accumulated during several years of successful protection is considered more serious than the moderate damage done by controlled burning every year or two, relative costs being also taken into account. For some years now controlled burning has been done in the resin tapping areas of *Pinus longifolia* in the Punjab and the United Provinces, and more recently it has also been carried out through young regeneration as soon as it is large enough to survive in adequate quantity: the decision as to the necessity for these operations was largely the result of the terrible destruction to these forests, especially the areas under regeneration, in bad fire years, notably the incendiary outbreaks of 1916 and 1921. Controlled burning of young *sal* plantations in damp types where *sal* is only a fire pre-climax is also being tried out in Bengal and likewise that of grassy *Acacia Catechu* plantations where the fire risk is high.

Game-proof Fences

The damage done by browsing by wild animals, notably 'sambhar' and 'cheetal' became very evident when plantation work extended in Bengal, and game-proof fencing on a large scale was found essential for the establishment of most species. The realization of the important part the same factor played in the natural regeneration of *sal* (and incidentally many other species such as *Adina*) only came in the course of the special studies in the United Provinces already referred to. Game-proof fences on Bengal lines were first erected in 1928-29 in several 100 acre units; most instructive results were obtained, for it was not long before conclusive proof was forthcoming that deer browsing in certain localities was enough to prevent all progress of regeneration beyond about 4′-5′ in height, the top of every taller sapling being browsed back. Reduction of browsing incidence by fencing against game is now a routine measure in regeneration areas in these places.

VII. Silvicultural Systems.

About 1914 the prevalent silvicultural system under which Indian forests were worked was the selection system which implied the felling of all saleable trees which had reached a fixed exploitable girth unless there were definite reasons (such as need for seed supply) for retention, and was accompanied by improvement fellings of varying intensity for the benefit of the more valuable smaller trees. There were considerable areas under simple coppice and coppice with standards working, and only small areas under uniform shelterwood regeneration (as in some of the hill pine forests), or clear felling with artificial regeneration. Since that time, there has been a very pronounced trend in favour of systems with concentrated regeneration either natural or artificial. The shelterwood system has been adopted for nearly all the pine and deodar forests except on very steep and broken ground, and was first introduced into the plains *sal* forests in Collier's 1914 Working plan for the Haldwani division, to be subsequently extended to most of the plains forests of the province and beyond, in modified forms, in Bihar and Orissa, the Central Provinces and Assam. The 'Coppice with standards' system has tended to fall out of favour and simple coppice to extend, especially in the Central Provinces where it has subsequently been slightly modified to retain promising groups of young growth and to exclude inferior areas on which all existing cover is best retained.

The great spread of clear felling with artificial regeneration has already been described and is common in varying degree to all provinces. It has nearly all been at the expense of the old selection system though this must long continue over the greater part of area as the conversion is naturally a slow process. This change has affected teak bearing forests most fundamentally but, as noted, it has spread extensively in *sal* forests and mixed deciduous forests. The regeneration of tropical evergreen forest in this way is still under experiment being open to certain objections only applying in smaller degree to the types already mentioned. In this connection it must be noted that practically all the intensive statistical work hitherto done on crop increment has dealt with more or less even-aged crops, and corresponding data are seriously lacking for the uneven-aged or selection form of forest. Only in the last few years has any serious effort been made to collect growth and mortality statistics for selection forest and that almost exclusively in the United Provinces.

The last few years have seen a reaction from the unduly rigid application to all types of forest of the conversion to even-aged crops to less rigid variations of this system and even (following the present fashion in Europe) back to selection forms. The selection system as applied in such cases is however a very different matter from the old Indian Selection system which amounted to little

more than exploitation fellings of mature trees, and it approximates more closely to that of European practice calling for even greater care and professional skill than the even-aged shelterwood systems.

Though Indian practice was naturally founded on the European training and experience of the professional staff, it has in the course of time developed its own methods adopted to its own requirements and we now rely on our own efforts for continued progress. The position is well brought out by Sir Gerald Trevor in his account of Indian Silvicultural systems in the *Manual of Indian Silviculture*, now in the press.

VIII. Working Plans.

The prescriptions for the application of suitable silvicultural systems to a given area of forest, usually a divisional charge of 250–1,500 sq. miles, together with all other prescriptions for its systematic management, constitute what is termed a working plan. Good working plans are essential to sound forest management and the progress made in them during the last 25 years is one of the chief accomplishments of the period. Not only has there been an extension of the area covered by working plans so great that practically all forests at present capable of intensive working are now provided for, but the plans themselves are based on far sounder data thanks to the stock mapping, and enumerations carried out and the statistical studies already referred to. Excluding Burma and Assam, which still have large forest areas for which working plans are not needed at present, out of nearly 80,000 sq. miles requiring working plans only about 500 sq. miles of forest are without them (1934-35).

Working Plans were formerly all scrutinized and sanctioned by the Inspector General of Forests, but with the appointment of Chief Conservators this centralization fell into abeyance, though most provinces continued to send their plans to the Inspector General of Forests or the President of the Forest Research Institute for any suggestions they might like to make. This latter practice is still continued and has the additional advantages of keeping the Forest Research Institute informed of developments in the provinces and of enabling the Central Silviculturist to help the latter with information on the latest statistics and yield calculations.

Working Plan control, i.e., the check that the prescriptions of the sanctioned plans are actually carried out, has also greatly improved in recent years and Indian practice at least in the more advanced provinces can stand comparison with that of any other country. Another development of this period has been the attempt to organize satisfactory arrangements under which suitable areas of forest can be entrusted to the villages dependent on them for forest produced and grazing. In the Bellary Circle in Madras large areas were handed over to *panchayat* management and the

examples has been followed to some extent in the United Provinces hills and elsewhere. It is too soon to draw conclusions from these experiments.

IX. Utilization Research.

It would be out of place here to describe the work accomplished in Utilization research, but one or two investigations carried out in the forest call for mention. The chief of these is the study in progress of certain factors influencing the yield of resin from pine trees as this is primarily a biological subject calling for special research methods taking into account the many variable factors likely to influence results. The investigation in the United Provinces on this subject, which has been carried on in the last five years and is likely to be continued several years more, is one of the most carefully organized pieces of forest research known to the writer and should yield valuable results as well as add greatly to our experience in research methods. Forest management is naturally very closely bound up with intensity of forest utilization, for the more complete the utilization of the produce of a forest, the more intensive is the management possible and desirable. Thus all extensions in the uses of wood, whether for paper pulp, charcoal, poles or pit props, react on silvicultural practice, rendering possible thinnings and similar operations which may otherwise be difficult to justify on the score of expense.

The fuller utilization of forest grazing and fodder supplies should also be referred to as much attention has been drawn to it in the last few years. Investigations are in progress in the C.P., Bombay and elsewhere on the effects of rotational closure, seasonal grazing, varying number of acres per head, etc. Here again, satisfactory and practical experimental methods are difficult to devise. Experience must be gained and some years must elapse before definite results can be obtained, but at least an earnest start has been made.

X. Conclusion.

This survey should make it clear that Indian forestry has good grounds for claiming to have made very rapid and fundamental progress in the past quarter of a century. A considerable proportion of this progress can definitely be ascribed to a more scientific outlook in keeping with the trend of the times, as reflected by the provision for systematic research which has taken place during the period. Progress has been particularly marked in the improvement of working plans and the data on which are based both quantitative or silvicultural, and quantitative or statistical. The development of artificial regeneration, the improvement of natural regeneration technique and the application of improved silvicultural systems are conspicuous features in this general progress, and the evolution of research methods suitable for application to the complex biological problems presented by forestry is also worthy of mention.

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PROGRESS OF ENGINEERING IN INDIA DURING THE PAST TWENTY-FIVE YEARS.

By

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CONTENTS.

I. INTRODUCTORY REMARKS.

A chapter dealing with a subject so broad as that of Engineering in India during the past twenty-five years could be compiled only by soliciting the help of engineers who had, during this period, been in association with the various classes of work carried out. A generous response was made to appeals for assistance in this respect and the descriptions which follow below have, as will be gathered, almost in their entirety been prepared by engineers who are now in India and have been engaged upon the operations described or have had opportunities of acquiring a first hand knowledge regarding them.

Endeavour has been made to put on record, in section II of the chapter, the characteristics and the salient points in connection with a number of the great schemes which have been executed. Nothing more comprehensive than this could possibly be essayed in the space available. A technical description of any one of the schemes would, as may be seen from the minutes of the Proceedings of the Institution of Civil Engineers and of other bodies, in which such descriptions have been published, require more space than could fairly be allotted to a mere chapter. All that could further be done was to give foot-notes, to enable those who may wish to penetrate further to refer to the sources of more detailed information. This branch of the subject is dealt with in this section under the heads Irrigation, Railways, Electrical Projects, Ports and Harbours, River Control and Bridges, to each of which a sub-section is devoted. If the criticism be advanced that this list is not entirely comprehensive, it must be accepted : it is true that much has been done in other spheres of engineering activity, and that India, along with other countries, has made great mechanical progress also in other directions. But a representative set of headings had to be selected, with due regard to considerations of space, and the collector of the information is not unaware of the fact that he may be accused of having displayed, in making it, the bias of a Civil Engineer. If it is also thought that there are omissions under any of the heads, and that some projects have not received the mention to which they were, by virtue of their importance, entitled, then the compiler is in the happier position of being able to pass on some measure, at any rate, of the criticism to his collaborators. From all of which it will be gathered that this record of engineering work is

commended with some diffidence to the attention of the Indian Science Congress Association.

Whilst the second section of the chapter constitutes, as already explained, a brief record of some of the engineering projects which have been carried out in India during the past twenty-five years, it was felt that a third section of a memoir of this description could very appropriately be devoted to a branch of engineering activity closely associated with, but yet distinct from, the actual execution of the work. The engineer is increasingly dependent upon the conclusions drawn from the results of experimental investigations. Research of this nature has become almost a branch of engineering in itself. In particular, a vast amount of attention has in the last few decades been devoted abroad to the investigation of hydraulic problems of various kinds and the compiler was aware that India could in this respect claim to have played no unworthy part. It was, therefore, determined to invite the collaboration, among others, of officers in the Irrigation Service who could speak with authority on this subject, having themselves been responsible for much of the research which has been carried out. In section III will be found a record of much useful work of this nature which has been carried out in India and the direct practical results of the investigations are in many instances pointed out. It is possible that this section may, from its nature, be of closer interest to some readers of the Indian Science Congress Association's Jubilee Memoir than will the recital of the projects successfully executed, comprised in the second section. If so, it is fortunate that certain of the collaborators have felt the necessity for entering into somewhat greater detail in the descriptions of their work than will be found in section II. The full significance of experimental work of this nature cannot always readily be grasped through abbreviated accounts and the reader will be able, if he wishes, to follow in some detail the nature of the work done by the investigators in the solution of their problems.

In this connection, too, it is realized that the account given by no means comprehensively sets forth all the work of experimental investigation carried out both by engineers and by those who work in association with them in this truly international sphere ; and the statement given below will have served its purpose, if it succeeds only in indicating that engineers in India have taken a full share in the research work incidental to engineering problems, when these are attacked by modern methods.

II. Engineering Projects carried out and general progress made.

(i) Irrigation.

Mr. M. T. Gibling, Secretary to the Central Board of Irrigation, below a graphic account of the advance which has been made

in Irrigation in the whole of India since 1912. It is right and proper that Irrigation should have the leading place in a Memoir of the nature, for, although India may have no cause to be ashamed of what has been accomplished in other branches of engineering, it is common knowledge that in Irrigation matters she stands pre-eminent, on account of the magnitude, individual and in the mass, of the projects which have been executed and also of the skill with which the enormous difficulties have been surmounted.

Mr. Gibling does not hesitate to touch on failures and disappointments and he shows how these have been in some cases retrieved. The allusions which he makes to the value of research in connection with Irrigation will, it is hoped, whet the appetite for the fuller treatment of this subject which is given in section III of this chapter.

(*a*) *General.*

Nature has (Mr. Gibling writes) bestowed her favours of rivers and rainfall on the sub-continent of India with a capricious hand. While some areas are completely devoid of rainfall throughout the year, there are others where it is recorded in hundreds of inches. There are few areas, however, which enjoy a well distributed precipitation throughout the year as is usual in the British Isles, and it is only in such limited areas that the natural resources of fertile land and sunshine can be put to full use without artificial supplies of water. It is in the provision of these artificial supplies that the irrigation engineer has found scope for his activities.

The provision of a supply of water as a substitute for rainfall has no doubt been practised on this planet since the creation of man, and even to-day the simplest methods of lifting water from streams or holes in the ground in animal skins are in use. And although on the other hand science has shown her influence in the development of the up-to-date methods generally employed, the principles remain unchanged. The earliest irrigators must have found the benefit of damming a stream for storage when supplies were running short, or to 'head up' and provide a gravity supply in a small off-taking channel. It is almost certain too, that the existence of sub-soil water was an early discovery and that that source of supply was tapped when other supplies failed. It is the increase in population that is responsible for the application of these principles on larger scales, by which vast areas in many parts of the world have been brought under cultivation by the aid of irrigation. And on account of India's large and rapidly increasing population, and her natural resources of water and fertile land, she leads the world in this science to-day. In fact, the area now under irrigation in India is greater than the irrigated areas of the next five leading irrigating countries including the United States of America. Much of this development has taken place in the last half century, but very rapid advance has been made in the latter half of that period.

India's population has grown from 315 million in 1911 to nearly 353 million in 1931, and is expected to reach 400 million by 1941 or earlier. In the past 25 years the area irrigated by Government works in British India has expanded from 22 million acres to 30 million acres, making an increase of 36%. The value to the country of this wide development can be appreciated to some extent from the values of crops grown under irrigation. In 1910-11, crops to the value of 62·5 crores of rupees were raised on irrigated lands, whereas in 1934-35, the crops grown under irrigation were valued at Rs.91 crores.

The Indian Irrigation Commission (1901–03) undoubtedly provided a fillip to irrigation development during the last quarter of a century, although some schemes, including the Lloyd Barrage Scheme in Sind, which they did not favour, have also been carried through. Their main consideration was the protection of the country from famine, but considerable progress has taken place not only for this purpose, but also for general development of the country, and the consequent uplift of the masses. Although very large areas in India were protected to some extent by inundation canals, full use was not made of the land and water available until perennial systems were introduced. On account of this advance, not only have the cultivators obtained security of employment and income, but the Provincial Governments have added substantially to their revenues. The Punjab Province may perhaps be particularly mentioned in this respect, since there has been more rapid development of irrigation in that Province than in any other.

(b) *Storage Works in Bombay and Madras.*

The principal schemes undertaken during the period under review can be classified under two main groups, namely, storage reservoirs and weir controlled schemes. The former are to be found mainly in the Madras and Bombay Presidencies where the absence of large perennial rivers renders the storage system of irrigation a necessity, whereas the latter are common in the North of India, where the rivers are fed from the snow-capped Himalayas. The storage works, which include in their number such magnificent structures as the Lloyd Dam at Bhatgar and the Wilson Dam at Bhandardara in Bombay Presidency, and the Cauvery Metur Dam in Madras, have surpassed any of the works of that nature constructed in the previous century. The Lloyd Dam with 21·5 million cu. ft. of masonry, and the Wilson Dam towering to a height of 270 feet above the river bed, are both classic works of their time, built with a gravity section of uncoursed rubble in hydraulic lime mortar. The Lloyd Dam stores water to feed the Right and Left Bank Canals of the Nira Valley, where an area totalling 834,000 acres is not only protected from famine, but is provided

with a secured and plentiful water supply. Similarly, the Wilson Dam, which stores as much as 10,086 million cu. ft. of water during the monsoon, releases it for perennial cultivation over an arid area of about 200,000 acres which was one of the worst famine areas in the Deccan. Although of outstanding dimensions, these works were, comparatively, of simple construction. Nevertheless there were many local difficulties in obtaining the requisite materials such as sand and hydraulic lime for mortar, whilst progress was hampered by the Great War. As a special precaution, Bhandardara (Wilson) Dam was constructed in the form of an arch of 6,000 feet radius although its section was of the 'gravity' type. This provided additional security for this dam which is the highest in India, and which at the time of its construction, was one of the highest in the world.

The Lloyd Dam has replaced the Lake Whiting Dam which was built during the period 1881 to 1892, and served an area of 270,000 acres on the left bank of the Nira River. With the expansion of sugarcane cultivation, the original storage was found to be insufficient and the Indian Irrigation Commission approved of the proposal to increase the storage, and expand the canal system. Although it was originally proposed to add to the existing masonry dam, it was eventually decided to build a completely new structure, owing to the technical objections to grafting new masonry on to the old. During construction of the Lloyd Dam, the old dam continued to store water for irrigation, and at the same time supplied hydraulic power for the generation of electricity which was utilized to drive stone crushers, mortar mills, pumps and other machinery during construction. The old dam was eventually submerged.

The Lloyd Dam is traversed by shafts and galleries to drain off any water that may leak into it, and also to permit inspection of its interior. It is also provided with instruments and apparatus for the electrical recording of temperatures, expansion and contraction, and deflection under pressure.

The Cauvery-Metur Dam in Madras was constructed in the period 1925 to 1934 and in addition to irrigating an area of 1,352,000 acres it has provision for the generation of electricity which will increase enormously its utility and earnings. This is the first large dam to be constructed in India in which cement was used in preference to lime. Before embarking on this new departure, the question was referred to a Sub-Committee of Chief Engineers of other Provinces who were asked to give their opinion on the following proposal :—

> 'The Engineer-in-Chief of the Cauvery (Metur) Project proposes to change the material of construction of the dam from cyclopean masonry in surkhi mortar to concrete in cement. The arguments in support of the change are that construction could be completed in 4 years with an earlier return

of revenue, that cement concrete is safer, is normal modern practice, and indirectly is cheaper.'

The Sub-Committee favoured the proposal, and construction of the dam in cement concrete was undertaken, 206,000 tons of cement being used. By the introduction of this change in material, it opened the way to the extensive use of machinery in construction, and the project is noteworthy on this account. Most of this machinery was specially imported from England, and included two gigantic concreting towers each 306 feet high and weighing 1,400 tons, which together were instrumental in the laying of 1,500 tons of concrete a day. To meet expansion and contraction of this mass of 54·6 million cu. ft. of concrete, the dam was built in sections of 126½ feet in length, which are connected together by U-shaped copper strips running the entire height of the dam, with the closed end facing the water. The dam is pierced by vertical shafts leading into a drainage and inspection gallery over 4,000 feet in length. The sluice gates are operated by electricity but can also be manipulated by hand-worked machinery. Electric power for construction purposes was supplied by the Mysore Government from Sivasamudram, a distance of 65 miles.

(c) *Central Provinces.*

Another storage scheme of note, although not in magnitude in the same class as those mentioned, but nevertheless of considerable value to many thousands of cultivators, is the Tandula Canal Project in the Central Provinces, which was undertaken as a protection against famine and brought to completion in 1923. The project comprises a twin reservoir on the Sukha and Tandula Rivers, and a canal nearly 69 miles long with distributaries aggregating just over 500 miles. The two dams are of earth work, one being 1½ miles long and about 70 feet high, and the other 1¼ miles long and about 80 feet high. The canal has a discharging capacity of 1,731 cusecs. The staple crop irrigated is rice, of which nearly 100,000 acres are cultivated annually. The reservoirs provide perennial water and dry season crops are also grown.

(d) *Northern India.*

Coming now to Northern India, we find that the last quarter of a century has brought into existence several gigantic schemes of supreme interest and importance. The Punjab, United Provinces and Sind have carried to completion projects which are unparalleled in any other country, and this development has brought large areas in the Northern belt of alluvial plains under perennial irrigation. The rivers which pass through these Provinces depend almost entirely upon the Himalaya Mountains for their supplies of water, and although the rivers are normally in full flow during the

monsoon months (July, August and September) only, when enormous volumes of water flow into the sea, there is a certain perennial flow from the melting snows. Although inadequate, these cold weather supplies enable perennial irrigation to be practised, and justify the expense of harnessing the rivers to feed the weir-controlled canals. In these vast alluvial plains there are very few outcrops of rock, and certainly none in the channels through which these rivers flow. Despite this absence of rock foundations, the irrigation engineers have constructed their weirs and barrages. But not without failures, and it is these failures which have been responsible for investigations through which it can now be said that a satisfactory solution to the problem has been reached. From meagre practical experience, and incomplete and inaccurate theories, works on permeable foundations were designed and constructed, but there was no substantial proof that they would withstand the monsoon floods, or the heading up in the cold weather, with a low or empty river on the downstream side. The chief troubles with this type of work were 'piping' underneath the work, or destruction of the downstream apron by floods or retrogression of the river bed. As a result of investigation in the field and in the laboratory, with mathematical substantiation, these difficulties have now been overcome. Two works of this type which recently suffered owing to the lack of satisfactory design are the Islam Weir in the Punjab and the Anderson Weir in Bengal. The investigations into the failure of these works have added considerably to knowledge on the subject of design and construction.

(e) *Triple Canals Project.*

The Triple Canals Project in the Punjab was completed in 1917, and brought under the command of irrigation an area of 3,900,000 acres. This project was considered to be the most difficult engineering work of its kind undertaken in India, and it embodied several outstanding features, such as the level crossing at Balloki on the Ravi River, where the waters of the Chenab and Ravi Rivers are deviated to the Lower Bari Doab Canal. The Upper Jhelum Canal presented unusual difficulties in design and construction since the head reach of it passes through broken rocky country, with many large cross drainages. Nevertheless, in spite of these numerous difficulties, the project was brought to successful completion and cultivation expanded in that area from about one million acres in 1916-17 to about two million acres in 1935-36. These figures, however, neither show nor measure all the material benefits of the project, and they cannot in any case measure its intangible benefits. Before the introduction of this scheme, the tract was sparsely populated by people who were compelled to subsist on wild berries, edible lizards, and camel's milk, and their chief occupation was cattle stealing.

(*f*) *Sutlej Valley Project.*

The next large Punjab work to be undertaken was the Sutlej Valley Project, which was designed to place the Sutlej waters at the disposal of large areas in the Punjab, and in Bahawalpur and Bikaner States. This immense scheme embodies four main weirs on the Sutlej, namely the Ferozepore, Suleimanke, Islam and Panjnad Weirs, and although some of the areas were previously irrigated by inundation canals, the chief object of the project was to open up and colonize waste lands, and this justified the financial outlay.

The design of weirs on sand foundations had not then reached perfection, and as already indicated, the Islam Weir failed two years after completion, and in view of the experience with this work, the Panjnad Weir was remodelled.

An innovation on this project, was the lining of a long length of one of the main canals to prevent seepage, and this work stands to-day as the finest example of its kind in the country. The head reach of the Gang Canal which is merely a feeder to the Bikaner Canal system taking off from the Ferozepur Weir, passes through very sandy country for a length of nearly 100 miles. In order to prevent excessive seepage in this long length, and possible ruination of the area by waterlogging, it was decided to line the canal for a length of about 80 miles. The lining consisted of unreinforced lime concrete of about 6″ thickness, the materials for which were supplied from Bikaner State where large supplies of lime *kankar* were available. The seepage in this length of canal is about 2 cusecs per million square feet of wetted surface, whereas, although the usual allowance for large channels is 8 cusecs, it is probable that seepage in this length would have been anything from 12 to 16 cusecs per million square feet. The value of the water saved has no doubt alone justified the initial outlay on the lining, but there must have been considerable saving in the maintenance costs of this channel compared with that of an ordinary unlined channel. Owing to the proximity of the Eastern Canal which runs parallel to it, the Gang Canal was not lined in the first five miles of its length for fear that the subsoil water pressure would blow up the lining when the canal was empty.

There was difficulty in obtaining suitable labour for this project and extensive use was made of mechanical excavators. Indeed, the large extent to which machinery was employed was both an innovation and a feature of the scheme. In addition to excavation it was employed for pumping, revetting, pile driving, stone crushing and the mixing and ramming of concrete ; the motive power being either electricity or compressed air.

Unfortunately, in the absence of a complete soil survey of the area to be commanded by the canals, it was subsequently discovered that large areas in the Bahawalpur State, although com-

manded by the new canals, were really unsuitable for irrigation, and after an extensive survey the commands of the canals were readjusted.

(g) *Sarda Canal Project.*

About the same time that the Sutlej Valley Project was in progress in the Punjab, the United Provinces were embarking on an extensive perennial scheme from the Sarda River, the main channel of which, the Sarda Canal, commands an area of about four million acres of culturable land in nine districts of the United Provinces, from Pilibhit in the north to Rae Bareli in the south. The Indian Irrigation Commission reported on the proposal for this scheme in the following terms :—

> 'There is probably no scheme for the introduction of canal irrigation into any part of India, which has formed the subject of so much discussion as that for a canal from the Sarda river for the irrigation of Oudh. Nor has any more difficult problem been laid before us.'

In 1920, however, the preliminary works of the Sarda Canal Project were commenced and it was nearly 9 years later when the canal was formally opened by Sir Malcolm (now Lord) Hailey, then Governor of the United Provinces. In addition to many difficulties during the Great War period when materials, staff and labour were in great demand in other spheres, and prices were high, this work suffered many set-backs. In the neighbourhood of Banbassa, where the headworks of the project are situated, the jungle and swamps presented exceptional difficulties by way of rendering the place unsafe and unhealthy to inhabit, on account of wild animals and malaria. Extensive clearance and drainage works had to be undertaken before it was possible to keep labour on the work. Except on the headworks, for which pumps particularly were required, very few mechanical appliances were employed, the vast majority of the work being carried out by coolie labour. In anticipation of the difficulty of obtaining and retaining labour, a steam 'grab' was introduced in 1921 for dealing with the under-water foundations of the barrage, but owing to the nature of the soil to be excavated it proved uneconomical and was sold. Light railway plant comprising 40 odd miles of track, 12 locomotives, and over 700 wagons of various types rendered efficient service, but there was considerable difficulty with pumps driven by oil engines, which was principally due to sand getting into the bearings. Electric plant was then installed to replace the oil engines, but that completely failed. Crude oil engines were introduced in 1925 and they proved satisfactory, and it was not until that year that good progress was maintained.

The headworks of this project consists of a barrage on permeable foundations, with 34 gates spanning 50 ft. each, and the

main canal (Sarda) which is 350 feet wide at the head, and has a system of channels 4,260 miles in length.

The culturable area commanded by the system is about 7 million acres, a large portion of which is devoted to sugarcane growing. In fact, this project is responsible for the boom in the sugarcane industry which the United Provinces have enjoyed.

There are several interesting features of this project such as aqueducts and siphons, and the Jagbura torrent crossing over the main canal is famous. The tail escape from the main canal is unique in that there are seven falls throughout its length, totalling a drop of 53·5 feet, while the channel is designed to carry 5,000 cusecs.

Taking advantage of the unhappy experiences on other projects in various parts of India, and in view of the comparatively high rainfall in some parts commanded by the scheme, the U.P. engineers incorporated an extensive system of drains in their project. When constructed, this system effectively drained a number of swamps and depressions subject to seasonal flooding, and provided an efficient disposal of rain water. This draining of 'jheels' (lakes) was objected to at the time by a number of the local inhabitants, but when the reclaimed land was brought under cultivation their objections were silenced. By means of this comprehensive drainage system, not only has the area affected been considerably improved, but the project has been free from the curses of waterlogging which have been the ruination of so many irrigation projects.

(*h*) *The Lloyd Barrage Project in Sind.*

This magnificent scheme, which came into operation in 1932, may be said to have originated in a proposal made by Lieut. J. G. Fife, R.E. in 1855, but the Indian Irrigation Commission in 1901–03 were apparently not convinced of the necessity for such a large perennial scheme in Sind, and made no provision for the work in their forecast of future expenditure on irrigation schemes.

With the expansion of irrigation in the Punjab however, grew apprehension in Sind that the supplies of the Indus were being depleted, and that unless a scheme was very soon introduced in Sind, it would be too late to obtain the benefit of the limited cold weather supplies. Largely due to the enthusiasm for the scheme of Sir George (now Lord) Lloyd, then Governor of Bombay, after whom the scheme is named, the project was sanctioned in 1923, and preliminary work was undertaken immediately. A journey through Sind in the hot weather is never to be forgotten, but that is not sufficient to realize the sufferings of those who laboured through all seasons of the year to bring this work to completion in 9 years. By making full use of the experience on other similar works, the designers of the project, and those who carried it into execution,

introduced a number of innovations, which made it the most scientific undertaking that India had known. The Barrage itself which is constructed across the Indus just downstream of the gorge at Sukkur, has a length of 4,725 feet between the faces of the canal regulators, with 66 spans 60 feet in length, each fitted with a gate weighing 50 tons. That portion of the structure which presented the greatest difficulties is below water, and the vast cofferdams which were built for the construction of the foundations, have long since been removed. Although the work of the Punjab investigators who have now evolved a solution to the design of this type of work, had not been commenced, the design of the Lloyd Barrage at Sukkur with its four lines of sheet piling, is found to be a sound and economical design. For the construction of the Barrage and the connecting head regulators of the seven off-taking canals, plant and machinery of the latest design were employed. Two dredgers, two paddle tugs and several mechanical excavators were obtained from England. An electric power generating station was established at Sukkur which supplied power to the workshops, quarries, construction machinery, and to the new Barrage Township which housed the staff employed on the work.

The headworks of the scheme cost about one-fifth of the total cost of approximately Rs.20 crores, the remaining Rs.16 crores being the cost of the canals, and minor irrigating channels, with their 1,889 bridges and regulators, and other subsidiary works. The main feature of the canal work was the large fleet of mechanical dragline excavators employed. Forty-six machines of this type with buckets varying in size from 10 cu. yds. to 7/8 cu. yds. capacity, supplemented by hand labour, which fluctuated between 30,000 and 50,000, were responsible for digging 279 million cubic yards of earth, of which about one-sixth was on the small water courses. The mechanical excavators were introduced owing to the shortage of labour in Sind, and the difficulty of obtaining sufficient outside labour at reasonable rates. Draglines had never before been employed on such a large scale in India, and although Engineer Erectors came from America and England to erect the machines and train crews, it was soon found that a separate organization was required to deal with the machines in order to keep them running satisfactorily. Numerous difficulties arose in connection with the machines or the staff, and it was only when a fully equipped workshop was established in Sukkur, where a large stock of spares was maintained, and major repairs could be executed, that this fleet of machines was able to keep up to the strain of working day and night through all seasons. Special mention must be made of the great part played by electric welding in all repair work connected with these machines. A portable welding plant was transported all over Sind for field repairs of every conceivable form, from the welding up of small teeth of broken pinions to the heaviest machinery repairs. Owing to the climatic conditions, intense

heat and cold, sand storms, and the exacting conditions under which these machines worked, the manufacturers soon found that a number of improvements in design were necessary. Considerable difficulty was experienced with the steam machines owing to brackish water, and in some areas river water had to be pumped a distance of 6 or 7 miles, but more than half the machines had Diesel engines, and that difficulty did not arise. Several world records for output were put up by these machines, and in spite of heat, dust and adverse conditions, they more than justified their employment, and besides working at extraordinarily low rates, they were undoubtedly instrumental in keeping down labour rates.

One very important measure which was adopted on this scheme was the centralization of the design of all regulators, bridges, buildings, siphons, etc., to be constructed outside the headworks area. This proved most satisfactory, and besides effecting a considerable saving in cost and time, it enabled the engineers in the field to devote their time to actual construction of those works and the canals. The centralization of designs also facilitated investigations into the latest practice on other large schemes in India. A large number of experiments were carried out at research stations at Poona and Karachi in connection with the designs, which resulted in exceptionally efficient results. Flumed regulators were generally adopted, and resulted in considerable savings in cost. Gates for regulators were standardized with the result that more favourable rates were obtained from manufacturers than could have been with a large number of gates of various dimensions. A special party was organized for the construction of reinforced concrete decking for standard steel road bridges. Standard steel centerings were prepared and they were conveyed from one bridge to the other on motor lorries, and by using rapid hardening cement, the decks of 48 bridges, with a total of 443 spans were constructed in a period of 18 months.

Most of the area commanded by this project was rectangulated and sub-rectangulated down to 4 acre blocks, and finally to 1 acre plots, the principal advantage being that it provides a definite and reasonable unit of irrigation and assessment of regular shape and size, instead of the existing 'survey number' of indefinite shape and size. This also greatly assisted the alignment and excavation of the new watercourses.

Taking advantage of the experience in the Punjab, the Sind engineers undertook extensive investigations into the possibility of water-logging in Sind after the introduction of the new perennial system of irrigation. A special organization was set up for taking borings on the rectangulation grid, in order to ascertain the nature of the sub-soil, the depth of the sub-soil water below ground level and the salinity of the sub-soil water. In order that it might be possible to watch the movement of the sub-soil water table after the commencement of perennial irrigation, permanent observation

pipes were left in some of the bores. The water levels in these pipes and in a number of open wells are being recorded periodically, and they will indicate when there is any likelihood of the sub-soil water level rising within the danger zone. The results from these investigations show that it is essential before any irrigation project is undertaken in the future, that a soil and sub-surface survey of the whole area involved should be made before the project is prepared.

The experience gained and lessons learnt on this gigantic scheme, which is ultimately expected to cultivate $5\frac{1}{4}$ million acres annually, will be of immense value to the engineers who will have the undertaking of similar projects in the future.

(*i*) *Other Schemes.*

Many other schemes of varying magnitude have been undertaken in various parts of India and Burma, and although they may not be prominent in comparison with the larger schemes mentioned, they are all of immense value and importance to the particular areas they affect. For example, the Damodar Canal Project in Bengal which was completed in 1933 has brought under command an area of 366 square miles. A factor which was largely influential in bringing this scheme into being is the fertilizing value of the silt carried by the Damodar River, and although irrigation was previously practised to some extent it was by means of a few temporary dams built across the river every year, the water being led to neighbouring fields in shallow channels devoid of regulators.

A scheme which is not only of economic value but also of political importance is the Upper Swat Canal in the North-West Frontier Province, which will irrigate on full development an area of 315,000 acres in the Peshawar District. This canal, which takes off from a weir across the Swat River at Amandara in tribal territory, flows in a south westerly direction for a distance of 4 miles between earthen embankments. It then enters the Benton tunnel which takes it southward through the Malakand Range into British territory. This tunnel is the most remarkable feature of the project. It is just over two miles long, 18 feet wide and $13\frac{1}{2}$ feet maximum height. It is the third longest tunnel in India and its excavation through hard muscovite granite took $3\frac{1}{2}$ years to complete. The canal then traverses the Dargai Nallah,—a natural stream between precipitous hills—for nearly a mile in a series of falls and rapids. Thereafter, owing to the steepness of the slope it runs in a boulder-lined channel almost 4 miles long to a point nearly opposite Dargai Fort where it falls 10 feet, and then bifurcates into its two main branches. Other interesting features which made the work difficult and expensive are the many siphons, culverts and aqueducts ren-

dered necessary by the broken country traversed by the canals. For the purpose of tunnelling the Malakand range a hydro-electric generating station was constructed from which power was supplied to the compressed air plant for drilling. This station has recently been developed under the Malakand Hydro-electric project from which power will be supplied for commercial, domestic and agricultural purposes in the Peshawar area.

Scientific advance in the design of irrigation works in the last quarter of a century has also been of advantage to Burma. One of the principal works undertaken recently was the re-modelling of the Shwebo Canal, which for a few years after its completion in 1911 gave considerable relief and benefit to the area commanded, and a good return on the capital invested. It then commenced deteriorating however, and in 1925-26 the work of remodelling the whole system was commenced. Due to insufficient knowledge of the design of canals in alluvium, the original designs were found to provide too steep a slope, with the result that scouring action rendered the channels unstable, and they rapidly became of little practical use. In addition to the channels themselves, the small outlets discharging water to the cultivators' channels and fields showed the necessity for considerable improvement. Although it cannot be said that these problems have been solved to perfection, investigations in recent years have resulted in designs which may be considered as perfect for most practical purposes. These designs are now being used extensively in new projects, and in remodelling old ones.

An innovation in the method of supplying water for irrigation was introduced in the Madras Presidency early in the period under review. This is the Divi Island pumping scheme, which marks the first attempt made in India to irrigate on a large scale by pumping instead of by the orthodox means of river weirs or storage reservoirs. The system can, it is true, and does at times, obtain a gravity supply direct from the river; but this is possible only during the flood season, when the river level is sufficiently high for the purpose. At such times pumping is not resorted to; but at others, and in the main, the system is dependent on pumps installed at the head or apex of the triangular island, which is the true delta of the river Kistna.

The main equipment, which stands above a stone-lined channel cut to connect the two arms of the river at this point, consists of eight 39-inch centrifugal pumps, each driven direct by a double-cylinder 160 B.H.P. Diesel engine running at 180 revolutions a minute, to which it is connected by a flexible coupling. The pumps deliver on an average 77 cubic feet of water a second through a lift of 12 feet. There is, in addition, an auxiliary plant, duplicated throughout, for priming the main pumps, circulating cooling water to the engines, drawing oil fuel from the storage tanks and running the dynamos that light the pumping station.

Water from the main pumps is discharged into two masonry-lined channels, one on each side of the engine house, which in turn deliver it to the main canal through two large Venturi meters. These have a diameter of 120 inches with a throat ratio of 1 : 3, and were at the time of their construction the largest of their kind in existence. The main canal, which is nearly two miles long, is provided with head sluices to enable it to obtain a supply direct from the river when conditions are favourable. At its lower end, it bifurcates into two branches, which feed the smaller channels forming the distribution system. All these waterways now aggregate 171 miles in length and command a gross area of 50,000 acres, or roughly half the island. The area actually irrigated has been increasing steadily for some years and is now just over 30,000 acres, yielding a net revenue of slightly more than Rs.1$\frac{3}{4}$ lakhs annually.

Though not completed till 1913, the system began to function in 1907. It has given entire satisfaction in every way and has practically trebled the area under cultivation. The machinery has more than fulfilled expectations in regard to capacity and performance and there have been only one or two serious breakdowns since it was installed 30 years ago.

(*j*) *United Provinces Hydro-Electric Schemes.*

The foregoing notes describe briefly the principal schemes undertaken in various parts of the country to utilize surface water in the cultivation of crops in areas where rainfall is scarce or capricious. A scheme on a large scale to make available for irrigation the water existing in the sub-soil has recently been undertaken in the United Provinces. To render this feasible on an economic basis, an electric power generating scheme was introduced as part of the project. A number of canals in this country are provided with falls in order to eliminate the difference between the natural slope of the country through which they pass and the slope at which canals in alluvium or similar eroding material can be constructed. The waste of power in the water falling at these sites has long received the attention of engineers, and although in a number of cases the power has been put to useful purpose in flour-grinding mills, etc. it has not been found economically possible to use it for generation of electricity for general purposes. Although the majority of the canals are perennial, there are periods during the year when they have to be closed down for repairs, or for rotations when water is scarce. A supply of electricity is not of much value if it is not continuous and dependable, and much thought has been given to the question of utilizing water for both irrigation and hydro-electric generation. Some of the falls on the Ganges Canal system have now been put to this double use by supplementing the hydraulic power with steam power, so that when

the canals are closed down the supply of power is not interrupted. The power generated at these stations is distributed over a large area in the United Provinces where it is used for commercial, domestic and agricultural purposes. In addition to providing the power stations, transmission lines, transformers, etc., the United Provinces Government have established 1,350 State tube wells, at which water is being pumped from the sub-soil or from rivers by electrically driven pumps. Besides providing water in areas where gravity supplies through canals are not available, the farmers have power at their disposal for the many agricultural operations they have to perform. Another similar scheme is shortly to be undertaken in the eastern portions of the United Provinces and there are signs of this form of development extending beyond the United Provinces boundaries.

(*k*) *The Future.*

With the rapid increase in the population of this country and the call for better conditions of the populace, the vast majority of whom are agriculturists, there is a growing demand for the further development of land suitable for cultivation, and, with it, the demand for water goes hand in hand. The Punjab has the largest area under irrigation, and apart from the general and indirect benefits received from her irrigation projects, the income of the Government has increased considerably as a result of them. But there is still room for further development, and two large schemes are under contemplation, one of which, the Haveli Project, is being commenced this year. Full use is being made of the experience gained on similar works, not only in the Punjab, but also in other parts of India and in other countries. The area which is to be served by this scheme is undergoing a comprehensive survey, not only of the surface soil, to ascertain its suitability for irrigation, but also of the sub-soil and sub-soil water. The drainage properties of the surface and sub-surface soils are of considerable importance and a chemical analysis of the underlying strata and of the sub-soil water, and knowledge of the depth from the surface of the sub-soil water, indicate whether any areas are liable to be water-logged or otherwise put out of cultivation by salt concentration on the surface. A detailed survey of the canal alignments is being made to ascertain the physical and chemical properties of the soils in which the canals will be excavated, and if the strata which are to be pierced are found to be of such a nature as to allow excessive seepage from the canals, steps will be taken to change the alignment, or the canal bed and sides will be treated to render them less pervious. Investigations are in hand with a view to lining a length of the main canal if it is found to be economically possible. Investigations are also in hand by the extensive use of models to evolve the most economical and efficient designs for the falls, regulators, bridges

and other appurtenant works. The canals are to take off from a weir which will be constructed at Trimmu, just below the confluence of the Jhelum and Chenab rivers. The design of this weir which is to rest on pervious foundations is undergoing detailed examination, aided by experiments on models, and the code of practice recently evolved by Punjab investigators.

(*l*) *The Central Board of Irrigation.*

In order to study and co-ordinate the research work of irrigation problems of an all-India nature, the Central Board of Irrigation, which consists of all the Provincial Chief Engineers of Irrigation, was constituted in 1925. This step was favoured by the Royal Commission on Agriculture in India, but they were of the opinion that the Board by itself was not sufficient to meet fully the requirements of the Irrigation Departments. They therefore recommended the establishment of a Central Bureau of Information for Irrigation which would 'establish and maintain a comprehensive library of irrigation publications, both Indian and foreign, which could be consulted by irrigation engineers and to act as a clearing house of information needed by Provincial officers. It should, however, be something more than a mere repository of information and a centre for answering enquiries. It should endeavour to reach a wider public than the Irrigation Departments and to keep agricultural Officers, and the public generally in touch with irrigation developments in India and abroad'.

This information Bureau has since been set up in the charge of the Secretary of the Central Board of Irrigation, who is an experienced irrigation engineer, and considerable use is being made of the Bureau by irrigation and agricultural Officers of the Provinces, and some of the Indian States. The Library, which now contains some 4,000 publications, is organized on up-to-date scientific lines, and literature is classified and indexed under the Institut International de Bibliographie decimal classification system.

The Central Board of Irrigation meets annually and discusses irrigation questions of administrative and technical importance, and the Board's Research Committee consisting of the Executive Committee of the Board and the Provincial Irrigation Research Officers, meets annually to discuss the research in progress at various centres. The Board issues technical publications on various problems, and also an annual report on the technical work of the Board, and a quarterly bulletin.

(ii) RAILWAYS.

The Railways of India in common with those of other countries experienced during the past twenty-five years great financial vicissitudes; but from the engineering point of view, which is that

now under consideration, there can be no doubt that this period has been one of remarkable progress. The following description, for which the compiler of the chapter is indebted to Sir Guthrie Russell, Chief Commissioner of Railways and to Messrs. Mackinnon and Ingoldby of the Railway Board, deals with the progress made by Indian Railways under two heads, namely, Civil Engineering and Locomotives. Though the descriptions are brief, they will it is believed serve to convey an impression of the activity which has during this period characterized railway policy in India through good times and through bad.

(a) *Civil Engineering.*

Expansion of Railways

The table below shows the increase in the route mileage of Indian Railways during the period under review :—

Total route mileage of all Indian Railways (including Burma).

At the end of	Route Mileage. Single	Double, Treble, etc.	Total.
1912	30,994	2,490	33,484
1935-36	39,426	3,693	43,119
Difference	+8,432	+1,203	+9,635

Among some of the more important or interesting new lines which go to make up this addition of nearly ten thousand miles may be quoted, the following :—

Itarsi—Nagpur.
Ballarshah—Warrangal.
Raipur—Parvatipur.
Villupuram—Trichinopoli.
Nushki—Zahidan.
The Khyber Railway.
The Central India Coalfields Railways.

Tracks

Perhaps the most important development in this connection is the fact that, at the beginning of the period under review, all rails and fittings were imported from abroad whereas for some years past the entire normal requirements of rails and fittings for the State Railways are manufactured in India.

The weight of rails in the track had had to keep pace with increases in the weight of engines and rolling stock and the heavier

demands made on the track on electrified sections and on those with heavy mineral traffic.

Thus, whilst before 1912, rails of 75 lbs. and 60 lbs. per yard were generally in use on main and branch lines respectively on the 5′-6″ gauge, the standard for main lines at the present day varies from 90 lbs. to 115 lbs. per yard. Similarly, on metre and narrow gauge systems the weight of rails has generally been proportionately increased.

Metal sleepers of various types in addition to wood have been in use on Indian Railways for many years in the past. Due to the rise in the price of wood in the immediate post-war period and the exhaustion of better qualities of timber in certain forest areas, considerable attention has been given in recent years to the use of improved types of metal sleepers.

Both steel and cast iron sleepers have been successfully developed in India and extensively adopted. Metal sleepers, though rather more expensive than wooden ones, are justified by their longer life and have advantages in respect to providing a better anchorage of the rails against creep movements due to high temperature variations. Recently, new types of metal sleepers have been developed with the object of increasing the lateral stability of track for high speed traffic and, in particular, an original type of Duplex joint sleeper developed entirely in India has been designed and adopted, the object of which is to overcome the weakness of the joints in the rails.

Important new bridges

The following are amongst the more notable Railway Bridges that have been constructed during the last 25 years :—

Hardinge Bridge	5894′ in length.
Ava Bridge (Burma) ..	3957′ ,,
Bassein Bridge	4361′ ,,
Roop Narain Bridge ..	2632′
Tapti Bridge	1863′
Silver Jubilee Bridge (Nerbudda)	4600′
Willingdon Bridge ..	2691′
Jumna Bridge (G.I.P.) ..	8156′
Jumna Bridge (N.W.) ..	1490′
Indus Bridge (Near Kalabagh)	3057′

In addition, many large Railway Bridges in India have been re-girdered or strengthened. Notable examples are the Upper Sone Bridge in Bihar, over two miles in length ; the famous Attock Bridge near the North-West Frontier and many others in all parts of India.

Manufacture in India

The Willingdon Bridge over the Hoogly river at Calcutta consisting of seven 350 ft. spans carrying double lines of railway with roadways contains 17,000 tons of steelwork and was the first large bridge

entirely manufactured in India. It was notable for the introduction of interchangeable processes of manufacture, in the adoption of which India has given a lead to other countries. The manufacture of bridge work in India to-day is a highly developed art and a scientific process. Nowadays, nearly all the requirements of steel bridges in India are manufactured in the country and considerable progress has been made on these during the past 25 years.

Signalling and interlocking, and Telephone Traffic Control

The old system of paper 'line clears' or permissions to proceed has largely been substituted on important lines carrying fast traffic by the use of electric token instruments which in addition to minimising delays afford a greater degree of safety when combined with fully interlocked stations.

The introduction of track circuiting in many large and busy station yards has simplified and expedited the movement of trains in the yards as well as adding to the safety of the travelling public.

The recent introduction of colour light signalling and the mechanical operation of signals and points on certain sections carrying fast and intensive traffic is in accordance with modern practice in other countries for speeding up movements.

Telephonic Traffic Control whereby a controlling officer in a central office keeps in touch with the movements of all trains over a large area of the line and thereby expedites their working and saves delays at wayside stations has been brought into use in recent years on a number of Indian Railways.

Important New Stations and Remodellings

Among the more important works carried out under this head during the period is the large new terminal station at Bombay Central and the remodelling of Cawnpore, Victoria Terminus (Bombay), Erode Junction, and Lucknow stations.

Traffic Yards

Since 1914 there has been a steady growth in the use of gravity shunting by means of 'Humps' for sorting and marshalling of goods trains in the more important yards on the principal railways, resulting in a definite saving in delay to goods in transit and in shunting engine hours.

Uses of reinforced concrete

There has been a progressive development on Indian Railways in the use of reinforced concrete particularly for small span slab bridges and arched bridges. The road overbridge constructed at Howrah by the East Indian Railway is a notable example of modern design consisting of a bowstring arch of 216 ft. span carrying a 30 ft. roadway designed for the heaviest or Ministry of Transport standard of loading. At New Delhi, there are many graceful reinforced concrete arches for Railway purposes. Recently, the Central Standards Office has produced a Code of Practice to regulate the design and construction of reinforced concrete work. In this connection, consideration has been given to proposals for the

special training of staff on Railways to ensure the satisfactory execution of reinforced concrete work in the field.

Investigations

During the last 12 years, a considerable amount of scientific investigation has been carried out under the aegis of the Railway Board with the aid of Technical Committees of Railway Officers. In 1928, it was decided to form a Standardization Office which has subsequently been placed on a permanent basis, the object of which is to co-ordinate the work of technical investigation and to put into practical shape the ideas and recommendations in the form of engineering standards for general adoption by Indian Railways. In the creation of these standards, efficiency is the first consideration but, in addition, the requirements of manufacture in India are kept prominently in mind. For example, in standard designs for steel bridge girders and structural work, only those sections of raw material are utilized which are produced by steel makers in India.

The Central Standards Office research investigations include experimental determination of the stresses in rails in order that requisite size and strength of rails may be properly correlated to the weight of axle-loads of engines and particularly with regard to the effect of speed in incrementing the effects of such loads. Exact information in this respect is being obtained by the use of electromagnetic recording apparatus specially designed for the purpose and it is anticipated that appreciable advantages and economies to Railways will result from these investigations.

Some 12 years ago, research was carried out by a Railway Board Committee into the dynamic effect of trains on bridges. As a result, an impact formula was produced which has since been adopted by the British Standards Institution as one of three alternative formulæ recommended.

The establishment on a firm basis of the Indian impact formula for bridges enabled suitable standards of loading for Indian Railways to be settled for the requirements of main and branch lines and for special developments of heavy mineral traffic.

More recently the system of pre-stressing girders has been introduced in India which has the effect of reducing the maximum stresses to which bridge members are subjected under load with resultant economy in design.

The work of the Railway Standards Committee for Bridges has also included proposals for suitable standards for road bridges in India.

In recent years, the system of electric arc-welding of bridge and structural steelwork has been developed and some important schemes of bridge strengthening have been carried out by this process.

The activities of the Central Standards Office in connection with track equipment have included the standardization of points and crossings, diamonds and slips, etc.

In addition, standard designs for the majority of requirements of signalling and interlocking equipment have been produced. All standards are subject to modification and improvement as experience in their use is obtained and until such time as they may be considered to be perfected.

(*b*) *Locomotives, etc.*

With the State Railway organization in this country, consisting as it does of a number of separate administrations under one central controlling authority, the advantages to be gained by introducing a measure of standardization have always been apparent. Locomotives were one of the first major items of railway equipment to which standardization was applied and as far back as 1904, with the assistance of the then British Engineering Standards Association a number of standard types of broad and metre gauge locomotives for use in India were evolved.

The designs of the majority of locomotives in use in this country to-day either conform with or are based upon these early B.E.S.A. designs, but in 1924 the Railway Board appointed a Standing Committee to review the question of locomotive standardization in the light of the changed conditions then prevailing and probable future traffic requirements. As an outcome of the recommendations of this committee a number of new standard locomotive designs for broad, metre and 2′ 6″ gauges have been evolved and slightly under 1,000 locomotives conforming with these new standard (I.R.S.) designs are now either under construction or in service on twelve different railways in India.

During the past twenty-five years the maximum axle-loads of broad gauge locomotives have increased from 17½ to 22½ tons. The 4-6-0 and 2-8-0 type locomotives which were the largest in service twenty-five years ago have now been succeeded by locomotives with the 4-6-2 and 2-8-2 wheel arrangements which enable wider fire boxes, suitable for burning the lower grades of coal available in India, to be adopted.

Similarly on the metre gauge lines, locomotives with maximum axle-loads of 8 tons have been largely replaced by locomotives with 10 and in a few cases 12 tons maximum axle-loads.

Although 4-cylindered locomotives with cranks set at 90° and 135° have been built during recent years for experimental purposes the two-cylinder arrangement has been generally maintained. Due, however, to their increased size and the greater degree of accessibility they offer, outside cylinders have been standardized and in agreement with locomotive development in most other parts of the world, locomotives with inside link motions of the Stephenson type are now being gradually eliminated.

In 1910 the first locomotives employing superheated steam were received in this country. Since that time all new locomotives

purchased have been so equipped and, in addition, some 1,500 existing locomotives have been converted to superheated steam at the time of reboilering. The economy in fuel consumption resulting from superheating in this country may be conservatively placed at 12%, and the economy in water in the region of 15%.

Simultaneously with superheating, piston valves replaced slide valves and during recent years poppet valves and valve gears of the Caprotti and Lentz types have been fitted to some 85 new locomotives and approximately 150 existing locomotives at the time of re-cylindering. Appreciable economy in maintenance and operating costs has resulted from the substitution of poppet valves for piston valves with short travel Walschaert valve gear. The difference is, however, less marked in the case of long travel piston valves except at the higher speed ranges.

Among other developments in locomotive design in this country, mention may be made of the standardization of rocking grates, arch tubes with security brick arches, soot blowers, top feeds and cylindrical self-cleaning smoke boxes with small doors and saddle supports, all features increasing the efficiency of boilers which have been applied both to new standard locomotives and renewal boilers for locomotives of pre-I.R.S. types. Similar remarks apply to long travel piston valves, box type pistons, narrow piston rings, etc., and every effort is made to increase the efficient use of steam in the more modern B.E.S.A. type locomotives when re-cylindering has to be undertaken.

Hollerith machine sorting and tabulating methods have been applied to the analysis of locomotive defects with the result that possibilities of improvements in detailed design have been brought clearly to notice. Consequently locomotive manufacturers, during the past few years, have been instructed to incorporate numbers of new features designed to reduce the cost of maintenance. The largest single source of expense is the maintenance of bearings.

Locomotives purchased during the past few years have been largely grease lubricated and a considerable number of existing locomotives have been adapted to use this form of lubrication. Although not considered an ideal lubricating medium, the use of grease has effected a material reduction in the incidence of hot bearings and enabled increased locomotive utilization to be obtained.

Simultaneously a number of investigations are being made with improved oil lubricated bearings; for example experimental locomotives have been equipped with bearings extended in length by 50% and with spring gear modified to suit. So far these experiments have been very promising and one engine has run nearly 100,000 miles without trouble. Roller bearings have, to a limited extent, been applied to the carrying wheel journals of both existing and new locomotives with marked success. On the latest experimental I.R.S. locomotives constructed, roller bearings have been applied to both carrying and coupled wheel journals and also

to the main side and connecting rod bearings on one locomotive, but it is too early yet to comment on these extended roller bearing applications. The same locomotives have a number of other features which have not hitherto been tried out in this country, such as steel fireboxes with all-welded seams and thermic syphons, 'Le Mestre' drawgear between engine and tender, cantilever cab platforms, etc.

Special alloy steels and irons are being experimented with for locomotive details subject to abnormal wear or corrosion and 'ferro-bestos' material has been introduced with considerable success at points where, due to abnormal bearing pressures, restricted rotational movement, or inaccessibility, no satisfactory form of lubrication is possible. In one instance a trial is being made with 'Silent Bloc' rubber bushes in which the elastic deformation of the 'bloc' permits of movement that would otherwise be taken up between two frictional surfaces.

During the period under review all main line locomotives in India have been fitted with electric head and cab lights and the safety of rail travel at night enhanced thereby.

Dynamometer Car

In 1930 a very completely equipped broad-gauge dynamometer car was purchased for the pooled use of broad gauge railways. This car has been intensely employed since its receipt and the various reports of trials and tests carried out cover a wide range of subjects and have furnished much valuable data relating to locomotive design. All the standard types of locomotive have been subjected to rating trials from which characteristic curves of their performance have been derived. A series of tests has been conducted to determine the resistance to traction of various types of stock, the relative advantages of plain and roller bearings, the effect of widening the gauge of track on curves and the relative merits of various types of feed water heaters and valve gear arrangements. An important series of current trials relates to the pressure drop between the boiler and cylinders and to improvements in steam distribution within the cylinders.

Carriages and Wagons

As in the case of locomotives, carriages and wagons have been subjected to a large measure of standardization of design. In 1918 at the instance of the Railway Board the Indian Railway Conference Association prepared a large range of standard designs covering broad, metre and 2′-6″ gauge coaching underframes and wagons. These designs were generally adopted by Railways until superseded by new standard (I.R.S.) designs based on the recommendations of a further standing committee appointed by the Railway Board in 1924 to take care of the standardization of this particular branch of railway equipment. This committee has also devoted much attention to the standardization of coaching bodies and coaching

body fittings and has been instrumental in introducing a considerable degree of uniformity in modern coaching stock on different railways and generally raising the standard of comfort provided in such stock particularly in respect to the lower classes.

Apart from general improvements in the standard of comfort provided the principal changes effected in coaching stock during the past 25 years have probably been the replacement of practically all 4-wheeled passenger carrying stock by bogie stock and the complete elimination of gas lighting in favour of electric light. During the latter part of this period a limited amount of what might be termed luxury stock for special services has been provided of which the coaching rakes employed on the 'Deccan Queen' running between Bombay and Poona and the 'Imperial Indian Mail' between Bombay and Calcutta in connection with the weekly mail steamers, are examples.

Experimental air-conditioned first class carriages are now under construction and it is anticipated that the greatly increased comfort which these carriages will provide will serve to make first class rail travel more popular and so justify an extended use of this class of stock.

In 1927 the Peninsula Locomotive Works at Tatanagar were purchased and remodelled for the purpose of manufacturing I.R.S. coaching underframes for all railways on a mass production basis; a development made possible only by standardization and which will again prove financially advantageous when the coach building programmes of railways more closely approach their normal proportions.

Broad gauge wagon axle-loads have generally increased from 14 to 16 tons during the period under review, a further general increase being prevented by the need for unrestricted movement of wagons over all sections of each railway and over all railways in the case of pooled wagons. A limited number of high capacity non-pooled wagons with 19 and 22½ ton axle-loads have, however, been constructed for use on certain sections.

Similarly on the metre gauge, wagon axle-loads have risen from 8 to 12 tons but only on a few sections, at present, can 12 ton axle-loads be employed and the carrying capacity of many of such wagons has, in the meantime, had to be marked down so as to give a maximum axle-load of 10 tons.

During recent years high tensile steel has been extensively employed in the construction of wagon underframes and the use of welding in place of or as a supplement to rivetted construction is now being actively investigated and a few experimental wagons of all and partially welded construction will shortly be built.

Rail Motors

To combat growing road competition and to handle better the limited passenger traffic offering on certain sections the need for providing fast passenger

carrying units of smaller capacity, more flexible in operation and less costly to operate than light trains composed of small steam locomotives and ordinary coaching stock, has been increasingly felt during recent years. To meet this need a few diesel-electric rail-cars have recently been acquired and it is probable that additional internal combustion engine propelled units of this kind will be placed in service on railways in the near future.

Operation

One of the most important measures taken to increase efficiency was the introduction of a completely revised system of statistics from 1924-25. The information brought to light has made possible not only a greatly improved day-to-day control, but has made it possible to handle many large questions of policy with much greater certitude than previously.

Apart from the improved financial control of maintenance and similar activities through statistics, great advances have taken place in recent years in the utilization of assets ; for example, for many years a mileage of 6,000 per month for main line engines was considered a satisfactory performance. Engines are now being designed for mileages of 12,000 per month, and two experimental locomotives are expected to reach a mileage in the region of 15,000 per month. The use of coaching stock has been improved materially by close attention to the diagramming and an insistance upon what is known as 'rake working'. Wagon usage has been increased very materially in recent years by increased train speeds, improved marshalling and shunting organization, improved signalling and traffic 'control' by long distance telephone, and a closer attention to detailed design and possibilities of reduction in idle time awaiting repairs.

Electric Traction

A notable development during recent years has been the electrification of the Bombay and Madras suburban railway services and the electrification of G.I.P. Railway main line sections between Bombay and Igatpuri and Bombay and Poona. Power for the Bombay suburban services is drawn from Tata's hydro-electric development schemes and to meet the power requirements of the main line sections a steam power house was constructed by the G.I.P. Railway at Kalyan. The electrified main line sections pass over the Western Ghats and regenerative braking is employed on the downward grades.

(c) *Development and Research.*

There has been a steady progress in Mechanical Railway Engineering technique during the last 25 years. The pace has been accelerated considerably during the last few years.

The various Standardization Committees that work in conjunction with the Standards Office (Railway Board) are constantly

bringing to attention possibilities for improvements and the results of large numbers of investigations into the properties of new materials and merits of new processes. Closely allied with this organization is the production of specifications through which centralized purchasing through the Indian Stores Department is made possible. Since 1930, 138 I.R.S. specifications have been published and 309 I.S.D. specifications adopted for use on railways. The Railway Board and The Indian Stores Department work in close collaboration in the production of specifications.

Great advances have taken place in recent years in the technique of painting. For a number of years test panels have been exposed by the Government Test House, Calcutta, but since 1936 the test panels have been exhibited simultaneously in different centres (Calcutta, Delhi, Lahore and Bombay) as experience has shown that the widely varying climatic conditions in India lead to material differences in paint life.

A current investigation is being made with the object of improving the water-tightness of wagons, doors and ventilating louvres and it is possible that special sections and baffles will be developed that will improve considerably upon those in use to-day.

The Railway Board, Indian Stores Department (Government Test House), Lahore University (Chemical Laboratory) and the Attock Oil Co., are collaborating in a research into the properties of lubricating oils. The research relates mainly to the properties of oils and metals under conditions of boundary lubrication. The object in view is an ultimate reduction in the number of heated bearings which are at present a source of heavy loss in railway operating in this country.

(iii) Electrical Projects.

Although it is realized that a recital of the progress made on hydro-electric schemes does not convey a comprehensive idea of all that has been done in electrical engineering in India, it is hoped that the record below will be accepted as in some sense representative.

(a) *Southern India.*

Major H. G. Howard, Chief Engineer for Electricity, Madras, has prepared the following statement of the development of hydro-electric sources in the South of India.

Madras has been slow in developing its hydro-electric resources and it was not until the formation of the Hydro-Electric Development Department in 1928 that any organized work was started.

Madras Presidency

Glenmorgan Scheme

This is a small auxiliary scheme (in the Nilgiris Plateau) constructed by the Government of Madras in 1929, for supplying power to the construction works of the main Pykara Scheme and also to the Municipalities of Ootacamund and Coonoor and some tea estates, till the Pykara Station came into operation.

The Glenmorgan Scheme utilized the unregulated flow of the Pykara river with a gross head of 675 feet. Provision was also made for drawing off water from the Glenmorgan reservoir when required. An intake from the river diverted water to the forebay by an open channel 2,100 feet long. From the forebay a penstock 1,780 feet in length was taken to the power station for feeding three water wheels.

Three 375 K.V.A., 400 volt, 750 R.P.M., 50 cycle, 3-phase alternators coupled to 500 H.P. Pelton Wheels were installed together with three 375 K.V.A., 400/11,000-volt step transformers. Power was transmitted to Pykara construction works, Ootacamund and other places at 11 K.V.

The station was closed in February 1933 as soon as the main Pykara Station came into operation.

Pykara Hydro-Electric Scheme

This is a high head scheme utilizing a fall of about 3,000 feet found available in the passage of the Pykara river in the Nilgiris District. The catchment area has an extent of 38 sq. miles. The flow though perennial is very irregular and often drops to around 15 cusecs in the dry season—the topography however embraces a number of feasible storage sites which could be devloped according to the growth of power demand. The estimated potential capacity of the full development is around 40,000 Kw. continuous or 60,000 Kw. peak. The initial development utilizes the regulated flow of the river with small storages of 58 million cubic feet in the forebay and 26 million cubic feet in the Glenmorgan Reservoir which is first storage site.

Civil Works. A diversion weir across the river 3 miles below the Pykara bridge diverts the stream flow to the forebay through a 7,000 feet open channel. From the forebay water is led to a surge tank by a 78″ diameter pipe 1,000 feet long. At the surge tank two 27″ penstocks branch off and feed 3 turbines through manifold piping and valves at the power station. The length of the penstock is about 9,300 feet.

Power Station. At present three 7,800 K.V.A. 3-phase 600 R.P.M. alternators coupled to 11,000 H.P. Pelton wheels are installed. Power is generated at 11,000 volts, 50-cycles and stepped up to 66,000 volts by means of three 7,810 K.V.A. 3-phase, 11 K.V.66/110 K.V. transformers. The supply to Nilgiris District is at 11 K.V. from an auxiliary bus in the power station.

Transmission and Distribution. A 50 mile double circuit 66/110 K.V. line transmits power to Coimbatore which is the main receiving station as also the chief load centre. 66 K.V. lines have also been extended to Erode, Trichinopoly and Negapatam, a distance of nearly 200 miles from Coimbatore. The longest direct transmission at 66 K.V. is 280 miles. But the loads at these places have recently been transferred to the Mettur Scheme which came into operation in June 1937. In addition to the main transmission lines considerable lengths of 11 and 22 K.V. distribution lines have been constructed, particularly in the Coimbatore District. At all load centres out-door step-down transformers have been constructed with the necessary transformers and switchgear.

Costs, Load and Revenue. The total capital expenditure up to the end of 1936-37 is nearly 2 crores of rupees, the revenue during the year being about 25½ lakhs. The scheme has already become self-supporting in the fourth year of operation. The load development has been much more rapid than anticipated, the peak load in June 1937 being over 16,000 Kw., which is in excess of the normal capacity of the station. The industrial development at Coimbatore accounts for more than 50% of the total load, and also the high load factor (more than 60%) of the station.

To provide for the rapidly increasing demand in the existing area and also the extensions to Madura and Ramnad Districts additional plant has recently been ordered. Additional storage of 500 million cubic feet has also been provided by constructing a dam in the upper reaches of the Pykara river in the Mukurti basin. The main features of the extensions are described below.

Pykara Scheme Extensions

Two 12,500 K.V.A., 600 R.P.M., 11 K.V., generators coupled to two 16,000 H.P. impulse wheels and two 12,500 K.V.A., 11 K.V./110 K.V. transformers have already been ordered, as also an additional penstock line. Provision is also made for installing at a later date two additional units of the same capacity. These extensions are expected to be completed by the end of 1938. It is also proposed to raise the voltage of the Pykara Coimbatore line to 110 K.V. About 150 miles of 66 K.V. lines to Madura and Virudhunagar are under construction.

The construction of the Mukurti Dam commenced in 1935. The dam is to be 90 feet high providing a storage of 1,600 million cubic feet, and costing Rs.21 lakhs. It has already been raised to a level assuring 500 million cubic feet of storage.

The load on the plants of the Madras Electricity Department is expected to exceed 20,000 Kw. and generation 100,000,000 units in the year 1937-38.

The Mettur Hydro-Electric Scheme

This is a Madras Government scheme which commenced operation in June 1937. The development consists in utilizing the irrigation supplies which will be let down from the Mettur Reservoir for the generation of hydro-electric power. The reservoir is of 93,500 million cubic feet capacity and the static head over the turbine varies from a maximum of 160 feet to a minimum of 60 feet. The dam is pierced by 4 cast iron pipes 8′ 6″ diameter for connection to 4 turbines.

As the potential output of the Mettur station is very variable due to the wide variation in head and discharge, it is proposed to generate and sell three classes of load, viz.,

(i) Primary power available at all times.

(ii) Secondary power subject to restricted use in dry months but which could be made into primary power by the assistance of the existing Pykara station (and later the Madras steam station).

(iii) Tertiary power generally available for eight months in the year.

The scheme is designed to supply power initially to the districts of Salem, Trichinopoly, Tanjore, North Arcot, South Arcot and Chittoor.

Power House. The power house is situated immediately below the Mettur Dam and in it are now installed three 12,500 K.V.A., 250 R.P.M. generators coupled to overhung type Twin horizontal Francis turbines of 16,000 H.P. each. Provision is made for installing a fourth unit at a later date. Power is generated at 11,000 volts, 50 cycles, 3-phase and stepped up to 66,000 volts (110,000 volts later) for transmission to various load centres. Supply to local industries near Mettur is at 11 K.V. from an auxiliary bus in the power station. The present load on the station is about 4,000 Kw. including the load which was till recently being supplied by the Pykara station.

Transmission and Distribution System. Two double circuit 66/110 K.V. trunk lines take off from the power station, one to Erode in the South and the other to Singarappet in the North. At Erode, the Mettur System is linked with the Pykara net work and both stations will be working in parallel for some months in the year. From Singarappet, it is proposed to extend the transmission system to Madras eventually. The initial transmission and distribution system consists of about 100 miles, of 66/110 K.V., 300 miles of 66 K.V., 100 miles of 33 K.V., 100 miles of 22 K.V. and 25 miles of 11 K.V. lines.

At all important load centres, outdoor transformer stations are provided for stepping down the voltage to 11 or 22 K.V. as

required. At Trichinopoly, which is an important station in the Southern area, two $\frac{+2500}{-2000}$ K.V. synchronous condensers are installed for ensuring proper voltage regulation.

The cost of the initial scheme is about Rs.1·4 crores.

Future Schemes

Investigations have been undertaken in connection with several other Hydro-Electric Projects and plans and estimates have been prepared for the following :—

Papanasam

A gravity dam 170 feet high to impound the waters of the Thambraparni River. The regulated flow to be utilized to generate power for use in the Tinnevelly and Ramnad districts. Ultimate installation 5–9,000 H.P. Vertical Francis Turbines and alternators operating at 600 R.P.M. under a static head of 330 feet. This scheme is expected to be sanctioned in the near future.

Periyar

Utilizing the waters of the Periyar Reservoir under a static head of 1,000 feet. Ultimate installation 4 Vertical Impulse Wheels of 13,000 H.P. each coupled to 9,000 K.W., 11 K.V. alternators 375 R.P.M.

Lamasinghi

Situated near the hills near Narasapatnam. A storage scheme to supply power to the Northern districts of the Province. Ultimate installation 4–7,500 H.P. Impulse wheels operating under a gross head of 1,500 feet.

Chettipet

A small plant of 1,500 H.P. to operate under a gross head of 12 feet situated on the Kistna Canal. Designed to operate in parallel with the Bezwada Thermal Electric Station.

Sivasamudram Hydro-Electric Scheme

This is a pioneer Hydro-Electric Scheme in Southern India constructed by the Government of Mysore and started operation as early as 1902, the scheme being started in 1899. It utilizes the gross head of about 410 feet of the Cauvery river falls near Sivasamudram where the power station is situated. The initial installation was a development of minimum waterflow of river which corresponds to 6,000 electrical H.P.; but within the last quarter of a century, it has grown to a comparatively big Hydro-Electric Scheme with an installed capacity of nearly 60,000 H.P. From time to time, numerous additions and modifications to the power station have been made to meet the increasing demand. With the construction of the Krishnarajasagara Dam across the Cauvery River (about 65 miles on the up-stream side of the power station) and other improvements and modifications of the forebay and the channel leading to it, the generating capacity of the station has been considerably increased. The following are the main features of the present installation :—

Power station. There are at present four 6,000 Kw. and six 3,000 Kw. sets installed in the station. Power is generated at 2,200 volts, 25 cycle, 3-phase, and stepped up to 78,000 V. for transmission to Bangalore, Mysore, Kolar Gold Fields and other places. The original Pelton Wheel generating sets have in later years been gradually replaced by bigger high head Francis reaction type turbines.

The present peak load on the station is about 40,000 Kw., the units generated during the year 1936–37 being approximately 224 millions.

The 'Kolar Gold Fields' has been and continues to be the major load for the Cauvery power scheme.

Transmission and distribution. The main H.T. transmission system consists of :—

(i) 4 circuit 78 K.V. line from Sivasamudram to Kankanhally.
(ii) A two circuit 35 K.V. line from Kankanhally to Bangalore.
(iii) A two circuit 78 K.V. line from Sivasamudram to Mysore.

In all there are now about 130 miles of 78 K.V. and 250 miles of 35 K.V. lines. In addition to the above, considerable lengths of rural distribution lines have been constructed by the Government, in recent years.

Travancore

The Government have small central stations with oil engine sets at Trivandrum and Quilon. The construction of an important Hydro-Electric Scheme is now in progress. Work was commenced in 1934 and the plant is expected to be in operation towards the end of 1938. Water is diverted from the Mannar River by means of a weir with regulating gates through a pressure tunnel nearly 10,000 feet long to 2, eventually 3, penstock pipes, operating under a static head of 1,980 feet. The initial installation will consist of 3–4,500 Kw. 750 R.P.M. 11 K.V., alternators coupled to 6,000 H.P. Impulse Wheels. The transmission voltage is 66 K.V. and about 150 route miles of line are projected. Receiving stations are being built at Kothamangalam, Alwaye, Quilon and Pallam, one of the most important loads being the Tea Estates in the Kannan Devon Hills where an initial demand of 1,500 Kw. is expected.

The scheme is capable of expansion, and transmission to the Peermade Tea District is contemplated in future.

(*b*) *Northern India.*

The compiler is indebted to Mr. A. P. Thomas, Chief Engineer, Punjab, P.W.D. (Electricity Branch), for the following description of Hydro-Electric developments in the North of India.

In the year 1921 the Government of the Punjab decided that a survey of the water powers of the Punjab should be made. The

survey was conducted by the Hydro-Electric circle and covered an area from Mianwali in the South to the waters of the Upper Sawat beyond Malakand in the North and from Kohat in the West to Murree in the East. The results of the survey and the examinations were published in seven parts under the title of 'Water Powers of the Punjab in 1924'. This very comprehensive survey shows that at least 86 sites suitable for the development of major Hydro-Electric stations exist in this portion of the Punjab alone. During recent years the main development in the Punjab has been limited to that of the Uhl River Undertaking. This is a scheme which is capable of development in three stages to an ultimate capacity of 12,000 Kw. of which the first stage of 48,000 Kw. has been developed and has been in commercial operation since April 1933.

The main features of the scheme are briefly; a three mile tunnel through the Dhauldar mountains, a range of the Himalayas, brings the waters of the Uhl and Lumbadag rivers at an elevation of about 6,000 feet above sea level through turbines in the Neri Khap situated about 4,000 feet above sea level, the tail waters finding their way back to the Beas river some 70 miles below the point at which the Uhl river joins the Beas in Mandi State. The generating voltage is 11,000 and the main transmission lines radiate at 132,000 volts from the Power House at Joginder Nagar to Amritsar, Lahore and Jullundur. From Lahore to Ferozepore and Lyallpur 66,000 volt lines radiate to supply these and certain other intermediate towns while the 33,000 volt line extends from Jullundur to Ludhiana supplying three towns in the way. Altogether 24 towns have been supplied and power has been made available to an area of approximately 12,000 square miles. With the second stage of the scheme increasing the power capacity to 72,000 Kw. it is anticipated that lines to Eastern and South Eastern Punjab will be built and this will probably occur at no far distant a date, as the present plant is being loaded up very fast, its present connected load being in excess of 26,000 Kw.

Apart from this hydro-electric development there is a small hydro-electric development which has been operating in Chamba State for 30 years utilizing the waters of the river Ravi for the supplying of power for lighting and pumping in Chamba town and another small plant has been in operation for at least the same length of time at Darjeeling.

A very interesting experiment was made with a low head development on a canal in the Punjab in 1920. The late Sir Ganga Ram received permission to supply water for irrigation purposes to a tract uncommanded by the canal system and for this purpose was allowed to instal a hydro-electric plant at a point where a fall of 8 feet was available in the canal. At this point turbines were installed and for many years this plant supplied electrical energy generated from the fall for supplying a battery

of pumps lifting water from the canal to the uncommanded area. Under the terms of the agreement when the period for which the Charter had been granted had expired, this plant became the property of the Irrigation Branch and has continued to operate satisfactorily ever since, although subjected to the difficulties experienced by plants of this kind when the canal waters are heavily charged with silt.

In the United Provinces, in 1931, the Hydro-Electric Circle commenced on the Ganges Canal Hydro-Electric Scheme. This scheme which was sanctioned for Rs.1,38,56,000 was to supply power at the following stations :—

1. Bahadrabad
2. Bhola
3. Palra
4. Sumera

totalling 7,500 Kw. These plants were duly installed and were operating in 1933 and as the number of tube-wells was increased by the United Provinces Government's embarking on a tube-well scheme it became necessary to provide further generating plants and an additional plant was installed at Salawa, so that the present full capacity of the Ganges Canal Hydro-Electric Scheme in the United Provinces is approximately 16,000 Kw.

(iv) Ports and Harbours.

The past twenty-five years have been a period of considerable expansion in connection with the major Ports of India. In almost every one of these Ports, which, however, are few in number compared with the size of the country and its length of sea-board, there has been a noteworthy development of the facilities available for ocean-going traffic, whilst, during the period under review, two new major Ports have also been constructed and opened to traffic.

It is proposed first to deal with the developments which have taken place in the older Ports and then to deal with the two newcomers. Whilst endeavouring to convey by brief descriptions some idea of the extent of the engineering developments which have taken place, it is felt that it will be appropriate to pay special attention to the nature of the problems which have presented themselves and which have had to be solved in order that the Ports might expand, or be brought into being, as the case may be. It will be readily understood, even from a glance at the map, that the varying situations of these Ports would be likely to give rise to diversity in the physical problems in relation to them and such has indeed been the case.

(a) *Madras.*

At the beginning of the twenty-five year period now under consideration it appeared that the major engineering difficulties in the way of the development of a first class Harbour at Madras[1] had, after many vicissitudes, been surmounted. The coast line at Madras runs almost due North and South. It consists of a sandy beach differing in no essential respect from that which extends for many scores of miles to the North and the South of it. The swell of the Bay of Bengal beats on this beach practically without cessation, there being very few days indeed during the year when the state of the sea is such that the surf ceases. Before the Harbour had been constructed, the trade of Madras had been carried on by means of surf boats of very light construction plying between the beach and ships anchored at some distance out to sea, these surf boats, each manned by four to eight men, being the only type of craft which could possibly pass unbroken through the heavy breakers. The construction of an artificial Harbour had been taken in hand in 1877 and the Harbour then formed consisted of a pair of breakwaters 3,000 ft. apart, extending seaward, parallel to one another, for a length of about 3,000 feet and then curving towards each other until they left an opening of 515 feet between their pier heads. This entrance to the area of 200 acres thus enclosed faced due East, towards the Bay.

The first misfortune which befell the new Harbour occurred in 1881, when a severe cyclone caused considerable damage to the breakwaters; and the question of their reconstruction gave rise to a controversy, lasting many years, on the question as to whether the existing form of the Harbour were the correct one. During the period in which the Harbour had been in use, shipping had undoubtedly been put to grave inconvenience. The enclosing breakwaters, even when undamaged, had not served their purpose of creating an area of calm water in which ships could lie securely at moorings and load or discharge their cargoes. The direction of the waves for some distance from the shore at Madras, as at most places along the Coromandel coast, is, within narrow limits. parallel to the shore, no matter what the direction of the wind. The slope of the sea bed is a very gradual one and the diffraction set up is such that there could inevitably be but little variation in the direction of the wave action. The consequence was that the Eastern entrance permitted the maximum of disturbance within the Harbour area which could possibly be set up through a gap of that width. It was therefore strongly felt that an entrance should be provided in a more suitable position and that the Eastern

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[1] *Proceedings of the Institution of Civil Engineers.* Paper No. 4228 by Sir F. J. E. Spring and Mitchell and Papers Nos. 3964 and 4301 by Sir F. J. E. Spring.

entrance should be permanently closed. The position which it was believed would be most advantageous was in the North-East corner of the Harbour. The scheme put forward was to demolish a stretch of the Northern breakwater and to continue the outermost, or Eastern, breakwater for a length of 1,200 feet Northwards in order to provide a shelter for this new entrance, such as would be necessary to enable ships to make use of it. The Eastern entrance was then to be completely closed.

This view had eventually prevailed in the teeth of intense and prolonged opposition and by 1912 the Harbour had been remodelled on these lines. Further misfortune was, however, in store and in November 1916, a violent cyclone, of the type to which this coast is most liable, struck Madras. In the course of a night the end of the sheltering arm, which consisted of a monolith 42 feet square and 58 feet high, weighing complete with its lighthouse about 5,000 tons, had been demolished, together with a length of about 130 ft. of the adjacent breakwater.

This was a serious situation and it was rendered still the more difficult by the fact that war conditions, then prevailing, made it almost impossible to obtain steel and equipment such as were necessary for making good the damage. It was nevertheless determined that, no matter what the difficulties might be, the sheltering arm should be restored and built on a reliable design.

The lack of steel for the construction of a 'caisson' however, turned out then to be an insuperable difficulty and the only possible course was to provide a semi-permanent Head to the breakwater, leaving over the final solution until conditions became more favourable. The problem thus presented was a difficult one. A semi-permanent Head had to be constructed in a situation which was obstructed by the ruins of the breakwater which had been destroyed and it had also to be carried out in such a fashion that a permanent Head could later be formed. The work was, however, successfully executed, the semi-permanent Head being built of 420 specially moulded concrete blocks, of varying shapes and sizes, surmounted by mass concrete, no steel caisson being comprised in the work.

When it became possible, after the cessation of the war, to obtain steel for the construction of a caisson, the forming of the permanent Head was taken in hand and it was completed by 1922. A caisson, 48 feet in diameter, was built and towed to the site and scuttled in position, being then sunk to a depth of 77 feet below low water. The gap between the semi-permanent Head and the permanent Head was filled with blocks weighing altogether about 9,600 tons. The reconstructed portion of the arm, like the portions which had preceded it, was built of 'slice' work, the sloping blocks resting on a rubble base 180 feet wide and 15 feet thick.

The disadvantage, referred to above, of a very low degree of tranquillity within the Harbour area, so long as the Eastern entrance was in existence, was not the only one with which the

Port of Madras had had to contend. It has been stated above that the wave action on the beach at Madras is generally parallel to the shore. There is, however, a sufficient lateral component in the direction of the breakers to give rise to a phenomenon, which has proved the bugbear of Harbour Engineers in many parts of the world, namely, littoral drift of sand. The heavy swell keeps the sand constantly in motion and each wave causes the sand, which it has punched, temporarily into suspension to travel a certain distance along the beach. Some of the sand is also kept permanently in suspension so long as the wave action is in any degree severe, and the sand is caused to travel along the beach by the inshore current which is set up by the lateral movement of the water. The predominant movement is due to the South-West monsoon and it has a Northerly trend, but there is also a less marked Southerly trend during the North-East monsoon. The quantity of sand which in this way passes any given point on the beach in the course of a year has been estimated at between half million and a million tons. It is a quantity which can only be measured under exceptional conditions, since the action can, and does, take place without any marked change in the profiles of the sea bed. It will be necessary to refer later to this action of the sea, when dealing with conditions which prevail at the new Port at Vizagapatam, further to the North. The construction of the breakwaters enclosing the Harbour area at Madras naturally has interfered with this process. The first result was an accretion of sand to the South, since the breakwater constituted a barrier to the movement of the sand; but wave action continued as before on the Northern side, whilst it was, at the same time, not 'fed' by a supply of sand from the South. The inevitable result was a very marked erosion along the shore to the North of the Harbour.

But with the entrance to the Harbour on the Eastern side, before the remodelling took place, serious trouble arose from the fact that a considerable proportion of the sand which was kept in suspension, and not deposited to the South, found its way, through the entrance, into the Harbour area and was deposited therein. The mouth of the Harbour was found to be silting up at the rate of 1 foot a year, 10 feet of draft having been lost between the years 1893 and 1903. This naturally necessitated persistent dredging and even this did not keep the accretion in check. It is gratifying to be able to record that since the new entrance was opened, no difficulty at all has been experienced in maintaining the depth of water in the Harbour.

The deposit of sand on the Southern side of the Harbour naturally continues as before, but the sand is prevented from reaching the new entrance by means of an extension of the Southern breakwater, known as the 'Sand Screen'.

It is also very satisfactory to note that the entrance at the North-East corner had completely fulfilled all expectations and with

the completion in 1920 of the new permanent Head, the necessary protection to shipping had been afforded. The transfer of cargo, to and from vessels lying at moorings, can now be carried on under the most favourable conditions.

Although the remodelling of the Harbour, very briefly described above, had solved the most urgent of the problems facing the Port, there was still the matter of the internal equipment to deal with. It was felt that matters were not entirely satisfactory so long as the whole of the trade of the Port had to be carried on by means of lighters and a certain amount of quay-side accommodation was urgently called for.

A quay was therefore constructed along the Western, or shoreward, side of the Harbour area. The quay wall, which comprised four berths for ocean-going ships, was built of monoliths of twin-octagonal shape and it is well equipped with hydraulic cranes. Four transit sheds, together with a line of warehouses, all well served by railway Connections, have also been provided. A ferro-concrete wharf has also been constructed on the Northern side of the Harbour and coaling and oil depots on the Southern. The past twenty-five years have, therefore, seen the completion of the remodelling previously taken in hand and the equipment of the Port on a scale adequate to the requirements of its extensive trade.

(*b*) *Bombay.*

Bombay found herself in 1912 with a modern dock system (the Alexandra Docks) quite recently completed and in use along with the older Victoria Docks.

It was nevertheless felt that the existing docks and wharves were likely, owing to the great expansion of trade, to become congested in the near future. It was therefore determined, as a first step, to make a complete survey of the Harbour with a view to selecting a site for a new dock system. The expansion of trade has not, in point of fact, since then been so marked as to necessitate additional dock accommodation and although features of importance, such as the construction of the new Ballard Pier, familiar to most travellers to India, have been carried out, the dock facilities at Bombay remain much as they were in 1912. Schemes of a very interesting nature for the improvement of the existing dock accommodation have been drawn up but it has been found possible to carry on the trade of the Port without embarking even on remodelling schemes.

As part of the survey of the Harbour referred to above, an interesting tidal model was, however, constructed and reference will be found in Section III to the experiments carried out by its aid.

(c) *Rangoon.*

The particulars given below of the developments in the Port of Rangoon since 1912 have been kindly given by Mr. W. D. Beatty, Chief Engineer of the Port.

Endeavour has been made in this chapter to subdivide the subject of Engineering into water-tight compartments, but Rangoon provides one of the instances in which this system breaks down. The Port of Rangoon, unlike the other river Port of Calcutta, had had in self-preservation to resort to large river-training schemes. Further reference to these schemes, to which Mr. Beatty alludes, will be found below under the head of 'River Control'.

From an engineering aspect (Mr. Beatty writes) the principal questions which have engaged the attention of the Commissioners for the Port of Rangoon during the last 25 years are those concerned with the conservancy of the navigation channels and approaches to the Port, the reconstruction and extension of the Wharf System, and the development of foreshore properties.

River Conservancy. The completion, in 1913, of the Upper River Training Wall, 10,000 feet in length, at a cost of Rs.1,38,00,000 was followed by the War period during which no works of any magnitude were undertaken.

Between 1924 and 1928, the King's Bank Training Wall was constructed on the right bank of the Rangoon River opposite its junction with the Pegu River, where erosion and consequent expansion of the River had led to deterioration of the approach channel to the Inner Harbour, the purpose of the Wall being to hold the River at a definite width.

The type of construction adopted consisted of a wall of granite boulders founded on flexible mattresses built of bamboo and brushwood which were sunk at slack water, a similar mattress apron with 3′ 0″ of stone cover being provided as a protection against scour. Above low water the wall was constructed of successive double courses of reinforced concrete slabs laid on edge and anchored together by tiebars suitably protected against corrosion, the space between slabs being filled in with rubble stone. The widths of the courses were 9′ 0″, 6′ 6″ and 4′ 0″ respectively. This form of construction, which was first adopted in the case of the Upper River Training Wall, has proved very effective and results in a substantial saving in the quantity of stone required. This wall is six thousand and ninety feet in length and cost Rs.38,10,000.

In 1936 a shorter Wall, 1,300 feet in length and generally of similar type, was constructed at Syriam Point, where high-water erosion had been active, a further length of 1,000 feet approximately being constructed of boulder stone without mattresses or slabwork.

Anxiety which had for a number of years been felt regarding the growth of the Outer Bar, a consequence of the natural development of the Delta seawards, led, in 1932, on the advice of Sir

Alexander Gibb and partners, to the construction in London of a Tidal Model, the object of which was to reproduce as far as possible the conditions which have led to the formation of the Outer Bar, to anticipate the probable tendencies in years to come, and to study the effect of possible remedial measures. In order to furnish the requisite data a large amount of special work was carried out by the Engineering and Survey staffs, including float and tidal observations, erosion survey, borings, laboratory work to determine silt contents, etc. Data regarding the discharge of tidal and upland water at different seasons of the year were furnished by a Hydrometric Survey carried out between 1931 and 1933. (Particulars of the tidal model are given below in Part III.) The conclusions arrived at from the model experiments confirmed the view of the Commissioners' technical officers regarding the source of the material forming the Outer Bar; they also indicated that there was no reason to anticipate worse conditions than in 1931, and that training works would be ineffective so far as the Outer Bar was concerned.

Wharf Developments, etc.

The period 1920–24 was occupied principally in making good arrears of maintenance due to shortage of staff, etc., during the war period.

Between 1924 and 1928 a large amount of work was carried out in reclaiming and developing foreshore properties, including the construction of an Import Salt Depot with storage for 60,000 tons of salt; the construction of a Depot for inland vessels, including godowns, transit sheds, roads, railways, and four screw pile pontoon jetties, the pontoons of which are 200 feet in length, served by double swing bridges, the jetties being carried on screw-piles.

Between 1928 and 1930 the Strand Market Wharf was constructed, joining up the separate (screw-piled) Wharf systems, each comprising three berths, at Latter Street and Sulu Pagoda. The new Wharf is of reinforced concrete, the front portion being carried on 7′ 0″ diameter cylinders and the remainder on 18″ × 18″ reinforced concrete piles. The Transit Shed is double-storied, equipped with electric lifts and external shoots. The Wharf carries six 3-ton electric Wharf cranes. The yard area is equipped with roads, railway sidings, open sheds, and a 10-ton electric transporter crane. The cost of this Wharf was approximately Rs.45,00,000.

In 1932, a new pontoon berth for sea-going vessels was constructed at Barr Street, forming a further extension to the main Wharf system. The pontoon is 500 feet in length, in two sections, and is served by four swing bridges carried on screw-pile approaches leading to a single-storied Transit Shed.

In 1936, this berth was converted into a Port Health Station, the Transit Shed, a steel-framed structure, being extended and equipped, and the yard area enlarged.

In 1937, the construction of a new two-berth Wharf, 900 feet in length, at Brooking Street was commenced; this will replace

a single berth T-head screw-pile Wharf built in 1882 which has hitherto served the Port Health Station but had reached the end of its economic life. The Wharf is designed as a reinforced concrete structure, the front portion being carried on three rows of screw cylinders, 3′ 6″ diameter, with 8′ 0″ diameter cast-iron screws, and the remainder on 18″×18″ reinforced concrete piles. Before deciding on screw cylinder construction for the Wharf head a number of trial cylinders were put down on the site and subjected to load tests with satisfactory results. The Wharf will be equipped with single-storey Transit Sheds, eight 1½-ton electric portal cranes, and a 40-ton electric crane travelling on a track normal to the face of the Wharf, which will take the place of a 30-ton Sheerlegs carried on the old Wharf.

The provision for two berths on this site will facilitate the reconstruction of the old Sulu Pagoda Wharf berths which will form the next stage in the programme of development.

For inland traffic the Port possesses a large number of pontoon jetties, the majority of which have timber-piled approaches; the latter are gradually being replaced by reinforced concrete structures constructed departmentally.

General

In other directions the Port has kept abreast of modern requirements. In 1932 a Wireless Direction-giving Station was installed some 50 miles from Rangoon at the mouth of the China Bakir River as an aid to navigation. A number of vessels of the Commissioners' flotilla have been equipped with wireless telegraphy and telephony, and two vessels have also been equipped with Echo-sounding apparatus. Both the former attended light vessels and the River light stations have now been replaced by unattended lights.

The Commissioners' Workshops are at present being reconstructed and partially re-equipped, and a 100-ton Chain-testing machine has recently been installed, there having hitherto been no equipment of this nature.

(*d*) *Karachi.*

The following particulars of the Engineering projects carried out in the Port of Karachi in recent years have been furnished by Mr. D. B. Brow, acting Chief Engineer.

The most important engineering work carried out by the Port of Karachi in recent years was the construction of four deep-water berths at the West Wharf, two 550 feet and two 600 feet in length.

The site for this work was on low-lying marshy land which was first reclaimed by means of a powerful suction dredger.

A quay wall, 2,400 feet long was then constructed on the Monolith System. Each monolith measured 30 feet square in plan and having four separate wells. The monoliths were sunk by grabbing out the wells by means of Goliath cranes. The maximum depth to which any monolith was sunk below level was 63 feet and the

minimum 56 feet. Very hard conglomeration of clay and gravel was encountered which in places required blasting. In order to assist the sinking, the monoliths were loaded with anything up to 2,000 tons of cast iron kentledge. Dewatering by means of electrically driven centrifugal pumps was also resorted to in many cases.

When the monoliths had been sunk to the required depth, the underside of the curb was cleaned up by divers and all soft material removed from the bottom of the wells. The wells were then plugged by means of cement concrete deposited by skips. The front wells above plug level were left empty and the back wells were filled with cement concrete of a weak mixture.

The quay wall was constructed in mass concrete above the monoliths. It is 18 feet in thickness and contains a conduit for electric cables and water mains.

The front of the quay wall was afterwards dredged to a depth of 34 feet below L.W.O.S.T.

Two of the berths have been equipped with 2-ton level-luffing electric cranes and also with Transit Sheds measuring 530 feet by 160 feet.

The berths are amply served by railway yards in direct communication with the North Western Railway system.

The work was commenced in 1923 and completed except for the equipment of two berths in 1930. These two berths are now being equipped.

The total cost of the work, including reclamation, amounted to over Rs.$1\frac{1}{4}$ crores and of the quay wall itself to just Rs.50 lakhs.

Between the years 1912 and 1936 the Karachi Port Trust also carried out extensive reclamation works. There were large areas of mangrove swamps surrounding the Harbour and of these a total area of one and a half square miles has been reclaimed. Formerly reclamation was carried out by a suction dredger but in recent years a powerful floating pumping plant has been used which empties the barges filled by the dredgers employed on Harbour maintenance. The disposal of dredged material in this way costs little more than dumping it out at sea and the reclaimed land is of considerable potential value.

(e) *Calcutta.*

The earlier equipment for the use of sea-going vessels in the Port of Calcutta consisted of a line of jetties on the bank of the Hooghly, opposite the centre of the town. To these had been added, and brought into use in 1892, the Kidderpore Docks in an area about two miles to the South of the jetties.

By 1912,[1] the expansion of trade had been such that further accommodation had to be found. The first stage of this extension

[1] *Proceedings of the Institution of Civil Engineers.* Paper No. 4842 by Ash; Paper No. 4841 by Pearson.

consisted of a line of five jetties on the river bank at Garden Reach, to the South or downstream side of the entrance to the Kidderpore Docks. These jetties are of steel screw-pile construction, screwing having been carried out by means of electric capstans. These capstans, the credit for which belongs to Messrs. Braithwaite & Co., an Indian firm, are believed to have been employed for the first time on this work, though they have been extensively used since then in other parts of the world. About 3,500 piles were screwed by their aid.

The Kidderpore Docks had until then been used almost exclusively for export traffic, but it was the intention that the Garden Reach Jetties should be used for both export and import traffic. Imports had previously been handled mainly at the Calcutta Jetties, which, as already stated, were close to the town. The design of the transit sheds at Garden Reach had therefore to be specially considered in relation to new conditions which would govern the handling of cargo.

These jetties were taken in hand in 1913 but progress on them was seriously interfered with by the war and the last of them was not completed until 1923. They are well equipped with electric quay and shed cranes and special attention was paid to the railway facilities in connection with them.

Before the Garden Reach Jetties were completed the second stage of Port extension had been taken in hand, namely the entrances, graving docks and the first set of berths comprised in a new dock system known as King George's Docks. An extensive area of land with a considerable river frontage had been acquired in 1907 for this purpose but the construction of the docks did not commence till 1920. The features which were added to the Port establishment as a part of these docks consisted of a lock entrance of dimensions more than adequate for any ship which had yet navigated the Hooghly, two graving docks, a pumping installation, an area of 42 acres of wet dock and five completely equipped quays. The five quays are only an instalment of those which it will be possible to construct in future, should the trade require it, and to serve by the same lock entrance ; for the layout of the docks makes possible the provision of twenty-five future berths. The layout of the docks was greatly complicated by the existence of an important main road, running right across the new dock system, and the plan adopted was settled only after prolonged consideration. The initial plans necessitated a high-level viaduct over 3,000 feet long, carrying the road, but it was eventually found possible to obtain all requirements without incurring this heavy expense.

The soil of Calcutta is of deltaic formation and the execution of heavy engineering works at great depths in such strata gives rise to serious problems. The levels at which it was necessary to found the walls of the entrances and the quay walls were considerably below those which had been adopted in connection with the

Kidderpore Docks, since the new docks were to afford greater draft for vessels and to provide for their entry and exit under all conditions of tide. When the Kidderpore Docks were approaching completion, an incident occurred which, only by a stroke of fortune, did not develop into a disaster of the first magnitude; the quay walls on either side of the dock moved bodily forward under the pressure of the earth behind. This occurred at a stage before water had been allowed to flow into the dock area and the forward movement was as much as 6 feet. The movement was only arrested by the prompt flooding of the dock area.

It had been the intention when the Kidderpore Docks were started to maintain the water at a level 9 feet below that of the quays. Since the docks have been flooded however, no Engineer had ever dared to lower the water level below about 2 feet 6 inches from quay level, lest the forward movement of the quay walls should re-commence. The water of the Kidderpore Docks has, therefore, to be maintained at this high level year in and year out; and as the level is well above that of the mean tides (and in fact above that of high water on all but a few days of the year) this means that enormous volumes of water have to be pumped year by year in order to maintain the water level in the docks.

It was intended to have the water level in the King George's Docks at that originally intended for the Kidderpore Docks, and whatever happened there had to be no change of plans owing to any such incident as occurred at Kidderpore. The movement of the quay walls at Kidderpore had been due to a conjugate, or horizontal, pressure from the earth behind, quite in excess of that which had been taken into account when designing the section of the quay wall, combined with certain unsuspected properties of the treacherous soil. It was very necessary, when planning the quays at King George's Docks, to take to heart the lessons learnt at Kidderpore.

The quay walls which had moved at Kidderpore had been built of mass masonry. Timber trenches had been carried down to the levels at which it was intended to found the walls. Experience had quickly shown, once the work was started, that if the walls were to be constructed in this fashion, it was necessary to build them in two halves since the area which could be exposed at one time in a trench at such low levels was definitely limited. When it was endeavoured to open out a greater area, the bottom of the trench rose, the sides collapsed and the heavy timbering was smashed to matchwood. After the incident, too, referred to above, it was found that the soil had been heaved up at a point in front of the walls some 200 feet away from an area behind the walls in which a corresponding subsidence had taken place. Such were the strata in which the work had to be executed.

It was determined to construct the King George's Docks' walls in monoliths instead of in mass work. It will have been seen

above that this type of construction had been adopted for the Madras and Karachi quay walls and it had also been followed in an extension of the Kidderpore Dock which had been carried out some eighteen years after the completion of the first stage. It would have been quite impossible to form timbered trenches in the soil of Calcutta down to the levels at which it was proposed to found the walls of the King George's Docks. Before that level could have been reached, a bed of water-bearing sand would have been encountered, which would have rendered further progress impossible. It was, however, quite feasible to penetrate this stratum by means of monoliths.

The monoliths were designed of a breadth considerably in excess of that of the Kidderpore Docks' wall, thus making for stability, but the main measure of security lay in the fact that the scheme of operations provided for the balancing, during construction, of the lateral pressures in front of and behind the walls. In the case of the lock entrance, this object was achieved by the construction of temporary masonry, standing above the finished floor level, in the monoliths of which the floor, as well as the walls, was constructed. In the process of forming the lock floor which had to be founded just above the top of the water-logged sand stratum, a fortuitous and unforeseen circumstance came to the aid of the Engineers. In sinking the monolith walls, a considerable volume of the water-bearing sand was drawn into the shafts of the monoliths and excavated through them. The effect of this was to lower the bottom of the clay resting above the sand and to make it possible to found the floor monoliths in greater security. Once the water-bearing sand were pierced by the floor monoliths, the completion of the floor would have been a matter of great difficulty as there would have been no means of staunching the upward floor of water through the monolith shafts. The same good fortune attended the Engineers in connection with the construction of the graving dock floors, which like those of the lock entrance were formed of monoliths. In the case of the quay walls, the wet dock area was flooded before the walls were completed, the subsequent excavation being effected by means of 'dragline' excavators. The water pressure in front of the walls served to balance that of the earth behind and equilibrium was achieved.

Another problem which had to be solved in connection with King George's Docks was that of the water supply. The water level which had been decided upon was, as already explained, 9 feet below quay level, or 6 feet 6 inches to 7 feet below the water level of the Kidderpore Dock. This level is approximately the mean level of the river throughout the year, but in view of the great difference between the river levels in the wet and in the dry season, the replenishing of the dock water by gravity throughout the year was impracticable. The water in the Hooghly is heavily laden with silt and, in the case of the Kidderpore Dock, a canal

two miles long has been provided in which the silt can settle and afterwards be dredged, before the water is pumped into the docks. The site which had been acquired for King George's Docks did not lend itself to the provision of a canal of this kind and such a feature, even if provided, would necessarily have cut across many lines of communication. It was concluded, after a series of observations, that if pumping operations were carried out only at certain states of tide, the quantity of silt could be so restricted that it would be possible to pump water direct into the Kidderpore Docks near their river entrance : and at the same time, advantage could be taken of the difference in water level between the Kidderpore and King George's Docks to obtain a gravity flow from the former to the latter, one pumping operation sufficing for the two dock systems, which are about a mile apart. This scheme was adopted, but for the *ad interim* phase, in which only the river end of King George's Dock would be in existence, it was decided to provide a pumping installation at King George's Dock which would serve both for dewatering the graving docks and for replenishing the water in the wet dock. This naturally entailed additional dredging in the King George's Dock in its initial stages. Eventually, the Kidderpore Dock canal can be taken out of use and the valuable area which it occupies may be devoted to a useful purpose.

King George's Docks were opened at the beginning of 1929. At a later date a new entrance was completed for Kidderpore Docks, which greatly facilitated the passage of vessels from and to the river Hooghly.

The foregoing is a very brief summary of the principal schemes carried out in the process of developing the major Indian Ports which were in existence before 1912. A brief reference will now be made to the two new Ports which have been brought into existence since that date.

(*f*) *Cochin*.

The Port of Cochin[1] has been built in a back-water. The entrance channel to the back-water was already in existence between British Cochin and the island of Vypeen but a depth of only about 10 feet of water existed over an outer bar, 600 feet wide, between the two-fathom contours. The great problem at Cochin was the formation through this bar of a deep water channel, which could subsequently be satisfactorily maintained. Opinions differed, and the main point at issue was as to whether such a channel could be maintained without its being necessary to dredge in the open sea, not only in the calm season, but also during the monsoon.

This problem, not dissimilar to others which have been encountered elsewhere, was solved at Cochin by the bold method

[1] *Proceedings of the Institution of Civil Engineers.* Paper No. 4756 by Bristow.

of a full-scale experiment. A dredger was purchased for use solely with a floating pipe-line. Such a pipe-line could only be used continuously in a comparatively calm sea with a swell of little more than two or three feet. To use it in the monsoon would have been quite out of the question.

It was realized that a portion of channel, dredged in a calm season, would by the next calm season inevitably have silted up to some extent. The problem therefore was whether a dredger of the capacity which had been provided could dispose in one calm season of the siltation which would have taken place in the preceding monsoon and in the same season also carry out sufficient original dredging. If it were possible in this manner to form a channel by seasonal advances, and to provide a section of channel which, throughout the monsoon, would, notwithstanding the siltation, still afford a draft sufficient for ships, then it would be possible subsequently to maintain the channel by the same dredger, once it were formed.

The first programme of open sea dredging was carried out in 1926-27 and the channel was completed in the calm season of 1928-29.

Since then the channel has been in use as an access channel to the berths which have been provided in the inner Harbour of the Port of Cochin, which is still in process of extension.

(g) *Vizagapatam.*

Until the opening of the Harbour of Vizagapatam,[1] no sheltered anchorage existed in the 1,000 miles of coast line between Calcutta and Madras.

The conditions at Vizagapatam resemble in one respect, those which have been described above in connection with Madras, but in that respect only. There is, along the Circars coast, a littoral drift of sand comparable in magnitude and in character with that which occurs at Madras. But whereas the Harbour at Madras had been constructed on the open sea bed, all ideas of following such a plan at Vizagapatam had been abandoned before the construction of the Harbour was taken in hand. Experience has shown how fortunate it was that such schemes, which were nevertheless very seriously considered, were not acted upon.

A channel runs at Vizagapatam between two hills and connects the sea with a back-water which is in an advanced stage of siltation. It was decided, instead of enclosing an area on the sea bed by breakwaters as at Madras, to deepen the channel between the hills and to use it for access to a land-locked Harbour to be constructed in the back-water.

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[1] *Proceedings of Institution of Civil Engineers.* Paper No. 5007 by Ash and Rattenburg.

The deepening of the channel of itself presented certain difficulties, since the bed was largely formed of rock; but the main difficulty lay, as at Cochin, in the dredging and maintenance of a channel through the open sea bed.

The opinion had been formed, before the construction of the Harbour was started, that the littoral drift of sand, if any, would not be of the nature of that of which the existence had been established at Madras. Nevertheless, doubts arose after work had been commenced, as to whether this conclusion was really a sound one, and preparations were made for encountering the difficulties which would certainly arise, should an active littoral drift be found to be present. Events proved that a northward drift of sand in no way less formidable than that at Madras was occurring at Vizagapatam during each South-West monsoon.

There is one very important difference between the situations at Madras and at Vizagapatam. At Madras, as has already been explained, the coast line is sandy and to all intents and purposes straight. At Vizagapatam, the southern of the two hills, between which the channel flows, projects out to sea, and is not fringed by a sandy beach. Had a Harbour been formed by breakwaters constructed on the sea bed, as at Madras, the inevitable result would have been that the bay between the new Harbour and the projecting hill would in a season or two have become completely choked with sand and the maintenance of an entrance would thereafter have become a matter of grave difficulty.

Once the facts of the situation had been established, the problem of the formation of a channel through the sea-bed at Vizagapatam was in certain respects not unlike that which had had to be faced at Cochin. The dredging equipment which was available could not be expected to form so long a channel in one calm season. The calm season at Vizagapatam is even more curtailed than that at Cochin, and a programme of not less than three seasons' dredging in the open sea had to be faced. But it was also certain that, when the channel were formed, means must be found by which dredging could be carried out on a large number of days throughout the year, in order to cope with the very great volume of sand, which would annually be driven by the force of the South-West monsoon into a restricted length of the channel.

It was believed that nearly the whole of the littoral drift took place within a zone extending some 600 feet seaward from the edge of the sea. It was possible by means of dredging to provide an area in which to trap a portion of the sand which would be impelled along the coast in the course of each monsoon, but the position would be far from secure unless it were made feasible for a dredger to work in this area for at any rate a part of the monsoon and so to hold the accretion in check.

The conditions which prevail at certain Harbours in South Africa, where the littoral drift of sand is very much in evidence,

were carefully studied before a scheme was put forward for dealing with the difficulties in connection with the entrance channel to Vizagapatam Harbour. The scheme which was decided upon involved the construction of an island breakwater on the Southern side of the channel. A gap of about 600 feet was left between the end of this island breakwater and the projecting hill to the south of the channel; and in the triangular space between the hill, the channel and the breakwater, a 'chambre d'apport', or sand-trap was dredged in which it was expected that the sand, which had been driven through the gap by wave action, would deposit as soon as it entered the comparatively calm area under the shelter of the island breakwater. The protection of the island breakwater would, it was believed, give the necessary shelter for dredging operations in all but very rough weather. It was evident that the alignment of the breakwater and the breadth of the gap must be carefully determined if these conditions were to be realised.

As has been stated above, the Harbour project was originally taken in hand in the belief that conditions of a much more favourable nature would exist in connection with the entrance channel. It was then considered that no Protective Work would be necessary for the maintenance of the channel and that the dredger would annually maintain it with ease by dint of a calm season's programme of work. By the time the contrary conclusions had been established, however, a great deal of progress had been made on the construction of the quays, etc., which were to be provided in the Harbour. Exceptional measures were called for if the Protective Work were to be completed by the time the berths and other features were ready.

It so happened that a vast tonnage of merchant ships was at that time laid up all over the world, on account of the financial slump. Such vessels could at that juncture be purchased for very small sums. It was therefore determined to utilize the hulls of two such ships as a working platform for the rapid construction of a breakwater. The ships were purchased in the summer of 1932. They were scuttled in the pre-determined position in the short calm season of 1932–33. They were filled with stone boulders, of which the neighbouring hills afforded an abundant supply, and adequately protected externally by similar means, particularly on the weather side, before the South-West monsoon rendered conditions so bad as to stop the progress of work.

The sand driven along the coast accreted during the monsoon in the sand trap, where the protection afforded by the breakwater made dredging possible on a number of days during the monsoon, sufficient for the maintenance of the channel. The Harbour was opened for traffic during 1933.

A working model by which the conditions which prevail in the outer part of the channel could be investigated was utilized

when arriving at the conclusions, on the strength of which the foregoing scheme was formulated. A brief description of this model will be found below in section III of this chapter.

(v) River Control.

Reference has been made above, and further particulars will be found below, to experimental investigations which have been made into the problems of the Port of Rangoon. The difficulties which, at the time when these investigations were made, were threatening the Port, were in the lower reaches and at the mouth of the river. At an earlier stage it had, however, been found necessary to take in hand a river-training work of great magnitude in the upper reaches.

The Rangoon river[1] at a point above the town takes a right-angled bend, which had resulted in the erosion of the concave bank and the formation of a deep embayment. Whilst adequate records had not been kept over a long period, it was known that the action had been in process for a long spell of years. The deep water channel had been diverted year by year further from the Rangoon foreshore and large sand banks had been formed on the right side of the river above the town. Erosion had set in and had commenced to undermine the jetties and wharves of the Port whilst the mooring facilities for sea-going ships had been seriously affected. This was the state of affairs which had to be corrected, if the amenities of the Port were to be preserved.

After most careful investigation, a scheme was adopted for the construction of a river training wall of a length of about 10,000 ft. The type of construction to be followed for this training wall had been a matter of prolonged controversy, the main point of contention being as to whether the wall should, or should not, be found on mattresses. It was eventually decided that mattresses should be adopted and the wall consisted of a mound of granite rubble, mainly deposited by hopper barges on a carpet of mattresses 230 feet wide. The mattresses, which were constructed of brushwood, were towed to the site and sunk in position by means of rubble. Mattresses of various forms have been used in many countries for river bank revetment and river training, but, as far as is known, they had never been employed on so large a scale in deep water in a strong tide-way.

Since there was no precedent on which to work, it was natural that there should originally have been considerable opposition to the scheme, and it is, therefore, gratifying to be able to record that not only was the scheme successfully executed, but that the effects upon the river have been in line with the expectations on

[1] *Proceedings of the Institution of Civil Engineers.* Paper No. 4174 by Sir G. Buchanan.

which the project was taken in hand. It is recorded that the deep water channel was brought back to the position which it had formerly occupied, affording a navigable channel of a depth of 50 feet below low water in front of the wall; that the sand banks which had threatened Rangoon had been very considerably diminished; that deposition had taken place rapidly inside the embayment; and that the dangerous cross current which had formerly occasioned such anxiety for the safety of the Port had been eliminated.

It is proposed to describe only two River Projects in this chapter and the second one is the restoration of the breach in the guide bank of the Hardinge Bridge. This bridge,[1] to which reference is made in Section II, crosses the lower Ganges by fifteen spans of 350 feet with three land spans of 75 feet at each end, making a total of 5,700 feet. The Piers consist of monoliths and they were sunk to as much as 150 feet below water level. The instability of the lower Ganges river has been repeatedly demonstrated and the measures which had been taken with a view to ensuring that, no matter how much it wandered in other stretches of its course, it would retain its alignment at the Hardinge Bridge, had been a matter for anxious consideration when the bridge was constructed. Training banks had been provided of a length of 4,000 feet and, on their completion, it was felt that the bridge was reasonably secure.

In 1933, however, the river showed signs of eccentric behaviour and, almost without warning, a breach about 400 feet long occurred in the right guide bank of the river. It was evident, also, when the mischief was first discovered that the process of undermining the bank was still in operation. A most serious state of affairs had developed and the safety of the bridge was clearly in jeopardy. Fortunately, the annual fall in the river level could not be much longer delayed, but before this took place, the breach had extended to 1,600 feet.

Urgent action was obviously necessary if the bridge was to be preserved and a start was made on the construction of a mole and back-water bund without delay. The early results were very disheartening as the stone which was dumped appeared to be dissipated immediately, and there was a stage at which the task appeared to be impossible. The time available for work was of course limited, for unless means could be found to secure the bridge before the river rose again, it was obvious that disaster was in store. By dint of tremendous efforts, the work was, however, completed just before the flood season of 1934 and although there were critical times during the ensuing flood season, the danger was eventually surmounted. To describe in full the measures which were carried

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[1] *Proceedings of the Institution of Civil Engineers.* Paper No. 5045 by Harvey.

out under the most trying condition in 1933 and the subsequent restoration work in the two following years, would require more space than can be devoted in this chapter, but the saving of Hardinge Bridge is in its way an outstanding feature of River Engineering work carried out under the most trying and anxious conditions. The quantities of ballast which had to be quarried, transported and deposited in the execution of this work were almost unprecedented and the saving of the Hardinge Bridge was achieved by a triumph of organization.

(vi) Bridges.

Dr. A. Jardine of Messrs. Jessop & Co. has dealt in the following paragraphs with the progress of Bridge Engineering in India.

The principal bridges built in India, during the last twenty-five years, have been railway bridges. Dr. Jardine treats his subject from a general point of view; but a list of the more important bridges, which have been constructed, has been given in subsection (ii)—(Railways)—above.

In one respect it may, perhaps, be thought that this appreciation of the subject is anticipatory, in that space is devoted to the new Howrah Bridge at Calcutta, work on which has only just begun. As, however, the most important task of the design of this bridge has already been completed, it will, it is hoped, be agreed that it would have been unjustifiable to await the Golden Jubilee of the Indian Science Congress Association before presenting the facts in connection with this bridge, which will, when completed, be one of the most important highway bridges in the world.

This chapter deals with engineering progress 'In India', and consequently stresses the subject of engineering effort 'In India'. Dr. Jardine raises the question as to whether the purely Indian effort should, in some cases, be greater than it is. When the chapter on Engineering Progress comes to be written for the Association's Golden Jubilee, it will be interesting to see whether the hopes, which are now expressed, have been fulfilled. Dr. Jardine writes :—

A correct appreciation of the great progress made in India during the last quarter of a century is only possible if her relative international status in this field is first clearly defined.

India is a land of many great rivers which interpose wide barriers between her important towns and districts, rendering communications difficult, if not impossible, without the aid of the Engineer, and resulting in her having some of the longest bridges in the world. Fortunately for her, from an economic point of view, the Bridge Engineer has not in any of these crossings been compelled to build what are known as 'Major Bridges', so that India's place in the world of bridges is not a very high one. She has at present not a single 'Major Bridge' within her territories.

but this condition, however, will not prevail much longer, for at the time of writing a new Cantilever Bridge of 1,500 feet span is in course of construction over the river Hooghly at Calcutta, and to this important structure further reference will be made.

The importance of a bridge as an engineering structure is measured by the magnitude of its individual spans, by which is understood the clear unsupported distance measured along the bridge between its points of support. Consequently a bridge of one great span ranks higher than a bridge having a multiplicity of smaller spans, even though the total length of the latter may be much greater. Bridges of 1,000 feet span and upwards are classified as 'Major' Bridges and the total number of these throughout the world is distinctly limited. Most 'Major Bridges' are to be found in the United States, which is, by a perponderating margin, the leading Bridge Building country of the world.

The cost of these large bridges is very great, for as the individual spans increase in length, their cost of construction rises in much more than simple proportion. No bridge therefore is built with a longer individual span than is necessary to secure the maximum possible economy of construction under the physical or other conditions governing the design. If no restrictions are imposed by navigation requirements, or other riverine conditions, the spans are kept as short as the physical conditions of the crossing will permit, and as the economics of the design may happen to dictate.

As already stated it is fortunate for India that it has always been possible to bridge her rivers with a series of comparatively short and economical spans, thus enabling her usually limited funds to accomplish much more construction.

Outstanding examples of the four principal types of bridges are given below :—

Suspension Bridges.—

Golden Gate Bridge, San Francisco, Span 4,200 ft.

Cantilever Bridges.—

Quebec Bridge, Span 1,800 ft.

Arch Bridges.—

Sydney Harbour Bridge, Span 1,650 ft.

Girder Bridges.—

The most common type, the maximum span being about 700 ft.

India has not so far a single notable bridge of any of these types. Her Suspension Bridges are all of light construction, carrying narrow roads and footpaths over inaccessible or difficult crossings on spans up to about 400 ft.

One Cantilever Bridge of 800 ft. span exists at Sukkur carrying the N. W. Railway over the Indus. It was constructed about half a century ago, and is now due for replacement as it is not up to modern loading requirements. It appears doubtful whether a new bridge would be of the same type, for it would probably now be considered possible and economical to construct one or more piers in the river bed, and so avoid the necessity for a large single span.

Of Arch Bridges India can only show a few examples, the spans of about 300 ft. being relatively unimportant.

The majority of India's bridges are of the Lattice Girder type, with Railway spans up to about 360 ft., and Road spans up to 450 ft. Her largest bridges, therefore, usually consist of a series of comparatively 'unimportant' spans, placed end to end, to make up the length required. The resulting structures however, from their very length, are of most impressive appearance, especially in the monsoon, stretching as they do in some cases for a distance of about two miles across the fast flowing and turbulent rivers.

In connection with the length of India's bridges it may not be out of place to refer to a world famous development of engineering practice due to one of India's pioneer Bridge Engineers. Although this principle was established long before the period now under review its benefits are still secured on all bridge construction where crossing wide and indeterminate river beds in level country. By the adoption of 'Bell's Bunds' on each bank, the length of bridge required is greatly reduced, but much judicious calculation is required to ensure that ample area under the bridge is left for the maximum volume of flood water ever likely to pass the site in a given period, whilst ignoring the almost indefinite spreading of the flood waters when the river rises.

The construction of a bridge involves four distinct stages :—

First the preparation of the design.
Second the construction of the piers and abutments.
Third the actual manufacture of the steelwork.
Fourth the erection of the latter in place on the piers.

Of these the second and the fourth must obviously take place at the site of the bridge, so that the credit for their execution is due to the Bridge Engineers on the spot. The first and the third, however, granted the necessary knowledge of all the conditions involved, may be carried out where most convenient.

India has in the present period made such great progress in every one of these subdivisions of the art of Bridge Engineering, that it is now possible for her to design and build any bridge she may require, and this with materials produced and manufactured entirely within her own borders.

Designs

Nearly every important bridge in India is a railway bridge, though of late years it is true that certain new railway bridges, as a secondary feature, have provided roadways on their structures. Several other old bridges, when no longer adequate for railway loadings, have been converted to road traffic. The various Indian Railway authorities have, therefore, been, and still are, responsible for the majority of India's important bridges. The present policy of the Government of India is to absorb, and to operate as State Lines, all the chief Indian Railway Systems. This process is yet far from complete and several big Railways are still controlled by Companies having their headquarters out of India, being largely independent of Indian control.

The State Railways to a large extent, and the Company Lines almost entirely, place the final responsibility for their bridge designs on Consultants abroad, this feature being particularly noticeable in regard to the steelwork itself, which in all cases is designed out of India. The same remark applies to most other public bodies in India.

The already firmly established connection with these Consultants, extending back as it does for half a century or more, is the chief reason for the persistence of the present system of referring automatically abroad all important matters in regard to bridge design. As affecting the development in India of a tradition in this vital aspect of bridge engineering, it is unfortunate that no change appears to be seriously contemplated. One of the immediate effects of this *a priori* reservation of the largest portion of India's consultative work is to render it unattractive to any Consulting Engineer of standing in his profession to establish himself in practice in the country. From the nucleus of such a consultative organisation once established, development would rapidly take place, and a body of Engineers skilled specially in the art of bridge design would soon become available.

Suitable talent undoubtedly exists in India, and with the removal of the present handicap it could easily keep pace with the rapid expansion in all the other departments of bridge engineering.

In spite however of this basic restriction, it is satisfactory to record great progress in recent years. The Bridge Departments of each of the important Railways, and to a lesser extent of certain other public bodies, contain many keen and skilful bridge designers, who would welcome the chance now denied them of executing in their own offices the whole design of the numerous important projects which pass through their hands. The same applies to the skilled technical staffs retained by the various private engineering firms, as a necessary adjunct to their greatly extended and highly developed manufacturing capacity, who now handle an appreciable volume of advanced design work.

Substructures and Piers

India's progress in regard to substructures and piers has not been so marked as in the other branches of bridge engineering, for the reason that at the beginning of the period under review she undoubtedly had sufficient skill and experience, and could have undertaken with confidence any contemplated work of this nature.

Perusal of the list of important railway bridges constructed during the period, as given in another section of this chapter, will show that much construction has been done. Technique has been improved and increased confidence has been gained, so that larger projects are now undertaken as a matter of course, which it is true might then have been regarded as notable.

The essential process of pier sinking in use in India remains practically unaltered, and she cannot record the execution of bridge substructure work by any of the somewhat novel modern methods being developed in other countries.

It should, however, be recorded that the almost universal system of sinking 'wells' for piers by 'open dredging' is supposed to have had its origin in India, and to have been developed from her ancient system of sinking her village wells.

The application of compressed air to assist the sinking process cannot be called a modern development, although here again technique has advanced considerably, and compressed air is now being applied in India much more commonly than before.

Recent important constructions include the piers for the Ava Bridge in Burma, and the Nerbudda Bridge in India, both involving the building in deep water of numerous piers far down into the river beds, making extensive use of compressed air during sinking.

The main piers for the new Howrah Bridge now under construction are unique both for their dimension and for the engineering problems they present in their execution. Located one on each bank, they are each 189 feet × 81 feet in plan, and will extend some 120 ft. below ground level. When completed each pier will carry a total load of about 100,000 tons.

Manufacture of Bridge Steelwork

In the manufacture of bridge steelwork India can record the most spectacular advance.

At the beginning of the period the manufacture of mild steel in India was just about to commence on a modest scale, and all raw material for local manufacture had to be imported. Practically all structural steel of any importance was manufactured abroad, and imported ready for erection. This was particularly true of steelwork for railway bridges, and almost entirely so for road bridges. Most requirements of this nature being satisfied from abroad, both as regards design and manufacture, Indian fabricators had to be content with the production of comparatively unimportant structures. Railway bridges up to about 40 feet span were made in India in small numbers, and road bridges on occasion up to say 150 feet span.

The position to-day is far different. The manufacture of mild steel is well established, and only a small percentage of India's requirements are imported from abroad. Expansion of the existing steel works is in progress, and the building of entirely new steel works is in hand, so that in a few years the position will be reversed and India should be able to export her raw and manufactured steel.

High tensile steel for bridge construction has been in use in other countries for many years, and it is very satisfactory to record that India has recently successfully undertaken the production of this class of steel, the adoption of which enables the Engineer to construct with increased economy bridges of longer span than before. The major portion of the new Howrah Bridge is being made from Indian high tensile steel.

The existence of indigenous steel works has had an important bearing on the rapid development which has taken place in the manufacture in India of all mild steel products,—of which Bridge superstructures are probably the most important. India's record is one which she may to-day regard with every satisfaction, for whereas not long ago nearly all her fabricated steelwork was imported, she is now practically independent of foreign supply, only a small proportion of her needs coming from abroad.

The culminating point in this development is the manufacture, now in progress in Calcutta, of the whole of the steelwork for the 1,500 feet span New Howrah Bridge referred to above. This structure is worthy of special mention as it will on completion be one of the world's 'Major Bridges', and will in fact as a Cantilever Bridge, rank third in importance, being exceeded in span only by the Quebec Bridge and the famous Forth Bridge, of spans 1,800 and 1,700 feet respectively. The bridge will cross the River Hooghly in Calcutta without intermediate support, a condition enforced not by physical difficulties, but by the fear that sinking piers in the river might cause damage to the régime of the adjacent Port.

The Hooghly is crossed a few miles higher up by the Willingdon Bridge, having spans of 350 feet, resting on intermediate piers sunk deep into the river bed, and higher up again at Naihati by the Jubilee Bridge, also on river piers. Up to the present, the superstructure of the Willingdon Bridge holds pride of place in India for massiveness of construction, and for length of span. It is also notable as having been fabricated in Calcutta from Indian steel.

Compared to the New Howrah Bridge, however, all other Indian bridges are insignificant, as will be soon realized when its gigantic structure begins to rear itself up from the banks, and to creep forward over the water to its final junction in the centre. The completion of this structure will entitle India to a prominent world position as a Bridge Builder.

In one modern aspect of bridge manufacture, India certainly has led and still leads the way, namely the mass production of bridge steelwork to such a degree of accuracy that all similar

parts are strictly alike and exactly interchangeable. This refinement of manufacture is also of great value during the erection at site. The difficulties are very great, but provided the necessary meticulous degree of accuracy can be attained, it tends to facilitate production, and the greatly enhanced initial costs are fully justified.

Nearly all the large bridges built in India of recent years, and referred to by name elsewhere in this review, have been constructed on this system. So great is the confidence in its reliability that it is now common to despatch complicated steelwork to site for erection, without having first assembled the parts together in the works. A notable recent example of this method is the Meghna Bridge, for the Assam Bengal Railway, now nearing completion. The component parts of the seven main spans of 323 feet were, for rapidity of manufacture, fabricated in three entirely separate works in Calcutta by different companies, and came together at the site with complete accuracy.

The steelwork for the Howrah Bridge is being manufactured by these up-to-date methods in the same three works in Calcutta.

In the short space of an article such as the present it has not been possible to go into detail in connection with various aspects of Bridge Engineering of which mention has been made, but it is hoped that in a general way the reader will have been able to appreciate the progress which has been made, and the lines upon which further developments are taking place.

III. Experimental Work, Research and Investigation.

The reader has been warned—or promised, as the case may be—that, having traversed the foregoing recital of engineering projects which have been executed in India and come to these descriptions of scientific investigations, he would find himself in somewhat deeper water. This applies, however, mainly to the work, described below, which has been carried out in connection with irrigation problems. The information given regarding other researches is of as general a nature as that dealing with the execution of projects. It is appropriate, too, that the data regarding irrigation research should be set forth in greater detail than those dealing with subjects such as marine work ; for whereas the former are of very general application it is seldom indeed that deductions reached in the investigation of a marine problem can unhesitatingly be applied to another case, however many the similarities between the two. The range of interest in a marine problem is thus comparatively circumscribed.

(i) Irrigation : in Bombay and Sindh.

Mr. C. C. Inglis, Director, Central Irrigation and Hydrodynamic Research Station, Poona, gives the following account of

Irrigation Research carried out in Bombay and Sind since 1916. Attention is invited to the highly practical results which have been achieved as a direct consequence of the research efforts. The experiments carried out with a view to obtaining guidance in the safeguarding of the Hardinge Bridge, the operations in connection with which have been briefly described in section II, subsection v, will, among others, doubtless be read with great interest.

In 1916 it was found (Mr. Inglis writes) that about 30% of land, otherwise suitable for sugarcane in the Nira Left Bank Canal Tract, was damaged by water-logging, salt efflorescence, or sodiumization; and that other Canals were rapidly becoming similarly affected; so, as all previous attempts to solve these problems had failed, a Division—called the Special Irrigation Division—was opened. It was found that successful drainage depended mainly on the porosity of the sub-stratum and so a very simple method of measuring porosities *in situ* was worked out.[1] It was also found that damage was largely due to water from irrigation of high-lying shallow soils finding its way under the clay layer of the valley lands, so that water, under several feet of pressure, was found in the clay zones. The first necessity was a soil survey, and it was found that trained observers could judge the soil profiles to a depth of 10 feet with a high degree of accuracy, from surface indications, especially weed growth, colour, 'bloom', and texture of the surface soil.[1] This survey cost 1 anna per acre. Working with these plans, land which was unsuitable, either because it would be damaged by irrigation, or because its irrigation would cause damage to lower-lying lands, was excluded from sugarcane irrigation; and the canal areas were divided into zones suitable for sugarcane, fruit trees, other perennial crops, and two seasonal or 'rabi' crops; and each type of crop was sanctioned on 6 year permits, in so-called 'blocks',[2] which were sanctioned in units of $1\frac{1}{2}$ acres, the whole area having been demarcated into $\frac{1}{2}$ acre plots, to fit in with the standard 3 year rotation usual in the Deccan.

At the same time land drainage experiments were carried out,[3–5] and it was found that where an outlet to a River, or a large nala, was available, drainage was economically practicable, and a large part of the areas when drained, was at once reclaimed. Consider-

[1] *Bombay P.W.D. Tech. Paper*, No. 13—'Soil and Subsoil Surveys in the Deccan Canal Areas' by C. C. Inglis & V. K. Gokhale.

[2] *Ibid.*, No. 16—'Irrigation in block system in Deccan Canal tracts', by C. C. Inglis.

[3] *Ibid.*, No. 14—'Improvement of damaged lands in Canal tracts of Bombay Deccan' by C. C. Inglis.

[4] *Ibid.*, No. 24—'Land Drainage Experiments at Baramati' by C. C. Inglis.

[5] *Ibid.*, No. 56—'Land Drainage in the Deccan Canals Area' by W. A. Evershed, with Note by C. C. Inglis (In Press).

able areas, especially those which were sodiumized, resisted reclamation; and so the question of reclamation had to be taken up, and six Bachelors of Agriculture dealt with this work in collaboration with irrigation staff. It has been found that practically all lands can be reclaimed by the judicious use of Gypsum, in conjunction with the growing of suitable crops under irrigation.[1]

Up to 1916 an unknown discharge of water was distributed by low-paid staff to an unknown area of crops (with different water requirements) for an unrecorded period of time. The result was chaos, waste and dishonesty. Steps were therefore taken to restrict water by constructing measuring devices [2] and outlets of a type which restricted the water supply.[3, 4]

The standard measuring device adopted was the Standing Wave Flume but where the head available was insufficient,—i.e., less than 10% of the depth of water in the channel—Venturi Flumes, (loss of head less than 1% at full supply) have been used.

The outlet which has been adopted is the Gibb Module,[5] which has no moving parts, yet the discharge is maintained constant within 3%, irrespective of upstream or downstream water levels, within working limits, by means of baffles, which come into action (when there is excess head available) as a result of free vortex flow. All these devices were adapted and improved after protracted experiments.[6]

In 1916 it was decided to remodel the Nira Left Bank Canal to pass 50% more water without interfering with irrigation, and conditions precluded adding extra spans to the Head Regulator. Model experiments were carried out and it was found that the coefficient of the existing sluices could be increased from 0·83 to 1·93 by adding a bell-mouth upstream and expanding the barrels downstream.

As a result 720 cusecs can now be passed with a loss of head of 0·17 ft. as against the previous loss of head of 0·38 ft. when only 480 cusecs were flowing—i.e., head required was reduced by 55%, despite 50% increase of discharge,[7] and the cost was only Rs.5,800 as against Rs.20,000 for additional spans—has this been

[1] 'Note on the experimental work carried out in the Baramati Experimental Salt Area in connection with the problem of reclamation of salt affected lands in Deccan Canal tracts' (Technical Paper under preparation).

[2] *Bombay P.W.D. Technical Paper*, No. 15—'Standing Wave Flume and Flume Meter Falls' by C. C. Inglis.

[3] *Ibid.*, No. 19—'Design of Distributaries and their outlets' by C. C. Inglis.

[4] *Ibid.*, No. 23—'Standing Wave Pipe Outlets' by C. C. Inglis.

[5] Technical Paper, No. 13 (class A)—Punjab P.W.D. A Bombay T.P., based on experiments, is under preparation.

[6] *Bombay P.W.D. Technical Paper*, No. 25—'Moduling Distributary No. 8, Nira Left Bank Canal' by C. C. Inglis.

[7] *Ibid.*, No. 54—'Model expts. to increase discharge of Nira Canal head regulator' by C. C. Inglis and D. V. Joglekar.

possible. Existing masonry works were provided with carefully shaped approaches and expansions, reducing loss of head to a negligible amount.[1]

Rock cuts were either widened or, where more than 15 ft. deep—so that widening was impracticable—,were lined, thus reducing the rugosity factor from 0·038 to 0·014.[2]

Considerable lengths of the Canal and Distributaries were remodelled to the correct, natural, shape[1] ($P=2{\cdot}67\ Q^{\frac{1}{2}}$; $R=0{\cdot}47\ (Q/f)^{\frac{1}{3}}$) (Lacey) where P=wetted perimeter, R=Hydraulic mean depth) ; but elsewhere the banks were widened and raised, and the channels left to reshape themselves to carry the increased discharge naturally—i.e., with widened sections and flattened slopes.

All these modifications were tested out by means of models, and results were far in advance of what was anticipated, both as regards efficiency and cheapness.

Pumping Poona sewage for disposal by irrigation started in 1918, water and effluent mixture being distributed as required, through twin channels of Distributary 5 of the Mutha Right Bank Canal. A Venturi Meter was installed at the head of this channel to measure the Canal water, and standing wave flumes to measure the effluent mixture—or water—in each of the twin channels. As sewage irrigation was a new practice, the Effluent Experimental Farm was opened in 1918 and placed under the Special Irrigation Division in 1919. This comprises 63 acres of land. Experiments showed that 225 lbs. of nitrogen per year, in the form of effluent, was ample to give an average crop of cane ; but to allow for loss, etc. the standard was fixed at 300 lbs. per acre per year. Experiments showed that effluent was a complete manure and gave an appreciably bigger outturn of cane per acre than that produced by standard manuring practice, and the land and outturns have been steadily improving under effluent irrigation.[3]

Up to 15 cusecs of sewage effluent is now received for disposal and although Distributaries 3 to 6 and Watercourses 19, 20, 22, 26 and 27 commanding a total area of 1,500 acres, are now supplied with effluent, the area is insufficient ; so experiments are in hand to find cane varieties and methods of irrigation to dispose of as large a dose of nitrogen as possible.

A scheme (*a*) for utilizing the gas generated by the sewage to pump the sewage and (*b*) to dispose of an anticipated increase of 50% sewage supply, partly by irrigation on a new area uncom-

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[1] *Bombay P.W.D. Technical Paper*, No. 20—'Model Expts. to ascertain the effects of partial lining of Malegaon Cut' by C. C. Inglis and D. V. Joglekar.

[2] *Ibid.*, No. 42—'Notes on Flumed Aqueduct; Remodelling existing Canal or distributaries to pass increased discharge ; Afflux caused by heading up water at Regulators ; Velocity distribution in channels' by C. C. Inglis.

[3] *Ibid.*, No. 17—'Effluent Farm (1918-19 to 1925-26)' by C. C. Inglis.

manded by a Canal, and partly by sludge digestion, and activation, has been prepared.[1]

The great success of this scheme has been due to *pumping, irrigation and research, having been under a single control.*

The Manjri Drainage Scheme, which drains a large part of the Effluent Area, was completed in 1936, and it has been found that irrigation with effluent expedites reclamation of land damaged by salt and sodiumization.

Rain and River Gauging was started in the Bombay Deccan, in 1902 and was handed over to the Special Irrigation Division in 1924. In 1930 the work was summarized,[2] formulae being worked out for maximum floods from 'fan' and 'Deccan' catchments. The former as now modified, is :

'Maximum discharge in cusecs per sq. mile $= \dfrac{7{,}000}{\sqrt{A+4}}$ where A is the area of the catchment in sq. miles.'

This formula is of world-wide application and holds for all sizes of catchment. The Report also shows the annual run-off from catchments in graphs.

In 1927, the Irrigation Development and Research Circle was opened with the object of applying results obtained from research in the Special Irrigation Division to the Deccan Canal Systems.

About this time hydrodynamic questions relating to the Lloyd Barrage and Canals Construction began to be referred for solution by model experiments. The most important problems dealt with were :

(i) Altering the Barrage design
- (*a*) to give minimum afflux during floods [3]
- (*b*) to make the standing wave from just downstream of the Barrage instead of at the end of the apron, where it would have set up destructive forces, which would have endangered the structure.[3]

[1] 'Disposal of Poona Sewage Effluent' (Technical Paper in Press).
Part I—Note on Effluent Distribution.
,, II—Poona Sewage Works.
,, III—Composition, analysis, losses in distribution and value of effluent as a manure.
,, IV—Water requirements of sugarcane : Experiments carried out during 1928–34.
,, V—Plot experiments at the Hadapsar Effluent Experimental Area, 1926–27 to 1933-34.

[2] *Bombay P.W.D. Technical Paper*, No. 30—'A critical study of run-off and floods of catchments of Bombay Presidency'. By C. C. Inglis.

[3] *Ibid.*, No. 29—'Experiments with various designs of piers and sills of Lloyd Barrage at Sukkur' by C. C. Inglis and C. G. Hawes.

(ii) The exclusion of heavy silt from the 7 Right and Left Bank Canals.[1]

(iii) The design of a new type of Regulator Fall suitable for Canals.[2]

The most suitable design of piers cut- and ease- waters was found to be 'equilateral arcs of circles'; though semi-circles were almost as good, and had the advantage that they were better where there was cross flow, and were less liable to catch floating matter.

The model had full supply discharge of 9·2 cusecs and a vertical exaggeration of 7 to 1, based on the formula :—

Vertical exaggeration = $(Q_p/Q_m)^{1/6}$ $(F_p/f_m)^{1/3}$ where Q_p and f_p are discharge and silt factors of prototype and Q_m and f_m of model.

In investigation (ii), standard methods of regulation were compared, viz. 'Still pond' and 'Open flow'. In 'Still pond' regulation, the undersluices are kept closed when Canals were open; whereas in 'open flow' some undersluices are kept open. Though 'Still pond' running was more successful either method was suitable for the Left Bank Canals; but 'Still pond' gave markedly better silt exclusion from the Right Bank Canals. Predictions were fully confirmed when the Canals were opened.

It was predicted that a silt bank would form along the right bank; and to prevent this, it was proposed that a long vane should be constructed upstream of the Canals on the right bank. This, alone, would have tended to pull the main flow of the River across to the right bank, so a similar vane was proposed for the left bank, and the two would have maintained flow free from heavy silt along both banks, (Reports not printed).

This recommendation was not acted on; it being decided to watch results. In the floods of 1936, the River carried an exceptionally heavy charge of bed silt, and the predicted sand bank formed along the right bank and silt entered the Canals. The original solution being no longer possible, experiments to find a suitable alternative have been started.

(iii) When the designs for the Sukkur Canals were being considered, it was found that none of the standard Canal Fall designs gave satisfactory results. A new type was evolved—'the proportional, Standing Wave, Flume, meter fall, with baffle and deflector'. —This design, when combined with a Regulator, is cheaper than any alternative and was found to be highly efficient in action—even where, as a result of scour, heavy retrogression had occurred down-

[1] *Bombay P.W.D. Technical Paper*, No. 45—'Silt Exclusion from Canals', Part I, by C. C. Inglis, and No. 46—Ditto. Part II with Appendices on the design of Models in accordance with the Lacey formula.

[2] *Ibid.*, No. 44—'Dissipation of Energy below Falls' by C. C. Inglis and D. V. Joglekar.

stream. It was also a highly accurate meter. Hundreds were constructed, and have proved highly satisfactory [1].

The Mithrao Canal in Sind suddenly began to silt as a result of changes in the River above the Makhi Regulator. A drop of 2′ 6″ into the Canal quickly disappeared and the discharge of the Canal began to fall rapidly. Model experiments showed that the difficulty could be overcome by constructing an approach channel from the outside of a curve of the River, a quarter of a mile upstream; so that top water was drawn, bed water passing down the River [2].

In 1931, staff was lent to the Development and Research Division in Sind, to assist in carrying out soil surveys on lines analogous to those followed in the Deccan—with suitable modifications. The whole of the area commanded by the Lloyd Barrage has since been surveyed [3]. Some two million acres have been classified in detail and, from the results obtained, it has been found possible to work out a system of classifying lands from surface appearance of the soil, the flora growing on the soil and the texture of the soil down to 3 ft. as ascertained from borings. This method of classification can be done at 1 anna per acre.

A system of observation pipes placed on a regular grid has been installed in the whole command of the Barrage and in a large area of the non-barrage canals. Regular observations are made throughout the year in these pipes and the results of the observations are plotted in April and October as contours showing the differences in sub-soil water table over a 12 months period and as contours showing lines of equal depth below the surface.

Work is now being undertaken to find out the change which has taken place in the salinity of the sub-soil water over the period of 5 years which has elapsed since the commencement of Barrage irrigation. The indications are that salinity has decreased.

The soil classification maps showing surface classification, which were prepared as a result of the work done by the Research Division in Sind, were found to be of great use in connection with the preparation of a road construction programme for Sind.

An extensive investigation has been made into the possibilities of lining canals in order to reduce or eliminate seepage losses and experiments on a large scale have recently been carried out on the sealing of a canal bed by means of an application of sodium carbonate.

[1] *Bombay P.W.D. Technical Paper*, No. 15—'Standing wave flumes and flume meter falls'. (New Technical Paper under preparation.)

[2] Technical Paper submitted 'Silt control at heads of Canals and Distributaries' by C. C. Inglis and D. V. Joglekar.

[3] *Bombay Engineering Congress Paper*, No. 136, Vol. 21—'Subsoil investigations made in the area commanded by the Lloyd Barrage and Canals Construction' by C. G. Hawes.

In 1930, a Hydraulic Research Laboratory was opened at Karachi for testing small models of various structures, and a large number of valuable experiments on these lines has been carried out[1–7]. In addition to these, some important experiments to suggest modifications to pass H.F. discharge through the bridges over Durani and Habib *Nallas* near Quetta in Baluchistan were carried out at Karachi. These experiments were taken in hand on the recommendation of a Committee of the Central Board of Irrigation on behalf of the Baluchistan Public Works Department. As a result of numerous experiments, modifications to suit each case were proposed.

Owing to a cloud burst, an unprecedented flood occurred in the Khari River, Palitana State, as a result of which more than 400 people were drowned. It was found that the high flood level was due to a standing wave forming, which caused about 2 ft. afflux upstream. This was eliminated at small cost, by removing a lime kankar ridge in the bed, and a Bridge was designed to pass a maximum flood with negligible afflux.

Deccan Canal administration had been seriously interfered with for many years as a result of heavy weed growth (*Vallisneria spiralis ; Potamogeton pectinatus* and *P. perfoliatus*)[8]. It was found that in Canals in which there was considerable silt in suspension, weed growth was small, and *vice versa* ; and so it was recommended that water should be fluctuated in the Pick-up Weir Basins at the heads of Canals to stir up silt as far as practicable. A protracted investigation, carried out in the field and laboratory, showed the relative effects of various factors on weed growth, light exclusion by silt, velocity, etc.—but the main point established was that water weeds can be killed off by suitably timed canal closures[9]. As a result, water weeds have been eliminated from

[1] *Bombay P.W.D. Technical Paper*, No. 27—' Experiments with models of Culverts made with Hume Pipes' by C. G. Hawes, H. S. Kahai and C. C. Inglis.

[2] *Ibid.*, No. 31—' Experiments with a model of Flumed Regulators' by C. G. Hawes and H. S. Kahai with a Note by C. C. Inglis.

[3] *Ibid.*, No. 32—' Experiments on a model of the Bifurcation of N.W. Perennial Canal at the Head of Warah Branch' by C. G. Hawes and H. S. Kahai.

[4] *Ibid.*, No. 33—' Experiments on a model of syphon for N.W. Railway' by C. G. Hawes and H. S. Kahai.

[5] *Ibid.*, No. 34—' Experiments on a model of Makhi Right Disty. ex Mithrao Canal,' by C. G. Hawes and H. S. Kahai.

[6] *Ibid.*, No. 35—' Testing various types of radial gates ' by C. G. Hawes.

[7] *Ibid.*, No. 30—' Models of standard vertical gates adopted in Lloyd Barrage and Canals Constn.' by C. G. Hawes.

[8] *Bom. Eng. Congress Paper*, No. XLVIII—' Some Factors affecting the design and working of Deccan Canals '.

[9] *Technical Paper ready.*—' Factors affecting the growth of water weeds in Canals and methods suitable to prevent growth ' by C. C. Inglis and V. E. Gokhale.

all the Deccan Canals except the Mutha Right Bank Canal, which cannot be closed on account of its being the source of Poona Water supply.

At the end of 1934, the Superintending Engineer, Deccan Irrigation Circle, was called in by the Hardinge Bridge Committee to carry out model experiments and report on measures required to safeguard the Hardinge Bridge across the River Ganges, on which nearly a million pounds had been spent, on repairs, during 2 years.

Five different sets of experiments were carried out :—

(i) Pier experiments, to determine the laws governing scour round piers, with (*a*) axial and (*b*) cross flow; and the best way to protect piers against scour.

(ii) Falling apron experiments to determine the way in which an apron, laid flat, launches under axial and curved flow conditions, when laid (*a*) on sand, and (*b*) on clay layers.

(iii) Experiments to determine the critical side slopes of pitched banks for stones of different shapes and sizes, and the final slope which the stones take up after launching under axial and curved flow conditions.

(iv) A large-scale model to determine the exact conditions when the Guide Bank slipped—in order to devise steps to prevent a recurrence

(v) Models of the River Ganges for the reach from Sardah, 40 miles above the Bridge to below the Gorai River, 15 miles downstream. The smaller model, called the pilot model, had a discharge of one cusec, a horizontal scale of 1/2000, and vertical scale of 1/200,—vertical exaggeration being 10 to 1. The large model, which is 600 feet long, has a discharge of ten cusecs, a horizontal scale of 1/500, and a vertical scale of 1/65—vertical exaggeration being 7·7 to 1.

Thirteen series of experiments have so far been carried out with the large model, 10 before the Hardinge Bridge Committee issued their Report [1]. These, tak n in conjunction with experiments (ii) to (iv), showed that the conditions which led to the breach were due to severe action caused by the Sarda Guide Bank, 19,000 feet upstream of the Bridge on the left bank, accentuated by the Damukdia Guide Bank, 11,000 feet upstream of the Bridge on the right bank. These Guide Banks turned 'high velocity, kinetic energy' into fiercely-eddying, surging flow, which cut away the toe of the Right Guide Bank, and so caused a serious slip, which later developed into a breach.

Alternative methods of reducing the attack were compared by model experiments, and the Committee decided, as a result,

[1] *Bombay P.W.D. Technical Paper*, No. 55—'Model investigations to protect Hardinge Bridge, over River Ganges, Eastern Bengal Railway' by C. C. Inglis and D. V. Joglekar.

to remove the stone from the Sara Bank, in order to reduce attack. This has proved successful. Reports on (i) to (iv) are under preparation; and Technical Paper 55 [1] deals with the first year's experiments with the large model.

At the present time the following *Specific experiments*, in addition to the Hardinge Bridge work, are in hand :—

(i) Training the Sarda River above the Banbassa weir at the head of the Sarda Canals, U.P.

(ii) Prevention of scour downstream of the Sarda Barrage.

(iii) Further experiments with the Sukkur Barrage Model to determine steps necessary to exclude silt from the Right Bank Canals, now that a silt bank has formed along the right bank.

(iv) Experiments to determine the protection necessary for the Waste Weir of the Spin Karez Reservoir near Quetta, Baluchistan.

(v) Experiments to exclude silt from the Faiz Wah Regulator, Khairpur State.

(vi) Experiments to exclude silt from Canals in Madras.

(vii) Experiments to protect pavements downstream of anicuts and regulators in Madras.

(viii) Design to increase discharge, and reduce afflux, of Krishna Right and Left Bank Head Regulators in Madras.

(ix) Training the River Jumna at Delhi.

(x) Prevention of scour downstream of Godavari Right Bank Head Regulators (Bombay).

(xi) Experiments to pass maximum flood over a high-coefficient Weir, designed to store maximum possible amount of water at Lake Arthur Hill.

(xii) Experiments to prevent damage to the Sina River causeway.

(xiii) Experiments to train Mula River at Rahuri.

(xiv) Experiments to prevent scour downstream of Aqueduct 3, Girna Canal.

(xv) Training Nalas upstream of Aqueducts 6 and 12 of the Nira Right Bank Canal.

In addition to the above, the following *Basic experiments* are in hand :—

(xvi) Bed movement of various types of silt under controlled conditions.

(xvii) Meandering of Rivers.

(xviii) Laboratory experiments into factors affecting losses from Canals.

(xix) Experiments with Standing Wave Flumes to ascertain effect of :—

[1] *Bombay P.W.D. Technical Paper*, No. 55—'Model investigations to protect Hardinge Bridge, over River Ganges, Eastern Bengal Railway' by C. C. Inglis and D. V. Joglekar.

(a) velocity of approach,
(b) depth upstream of hump on coefficient,
(c) position of upstream gauge,
(d) length of flume,
and (e) slope of glacis.

(xx) Venturi Flume experiments.

(xxi) The determination of factors affecting expansions downstream of Falls, Standing Wave Flumes, and Venturi flumes, to work out rules for designing such expansions.

(xxii) Experiments with a modified design of Crump Adjustable Proportional Semi-module.

It is estimated that the saving which has been effected by research on the Lloyd Barrage and Canals Construction exceeds Rupees 60 lacs and in the Deccan exceeds Rupees 40 lacs.

The success of the work has been due, to a large extent, to its being directed by officers who had had long experience of field work before they started research so that they were able to visualize problems with which they had to deal and, through exact knowledge of field conditions, were able to eliminate unnecessary work.

(ii)—Irrigation: in the Punjab.

Dr. Mackenzie-Taylor, Director of the Punjab Irrigation Research Institute at Lahore, gives under five heads, *a* to *e*, below, a most illuminating account of research work of a very varied nature carried out by him with the assistance of Dr. N. K. Bose and Mr. J. K. Malhotra. Dr. Mackenzie-Taylor's treatment of his subjects is broad and he gives a clear idea of the relationship between investigations which have been carried out in India and those which have originated in other countries.

(a) *River Model Experiments*

Introduction

Introduction of models for the solution of many intricate problems in engineering has seen the advent of an era of rapid development. Problems in which the interaction between forces is so complex that no mathematical solution is possible, but such problems of immediate practical importance have yielded their secret to model experiments. Most conspicuous has been the success of models in the fields of aerodynamics and ship-building. The theory and technique of such experiments have been developed to such a high degree of perfection that not a single steamship or aeroplane is put in action without its model having been fully tried in tanks or wind-tunnels previously. This is particularly true in the development of the art of flying which, apart from the high cost of full scale experiments, is attended with great danger to the life of the pilot and the machine.

This unprecedented development has mainly been achieved by closest co-operation between theory and experiments on models. In the aerodynamic laboratory of Prof. Prabdtl in Göttingen models play a very important part in unravelling intricate fluid movement, in building up theories such as 'Tragflugel Theorie', 'Grenzschicht Theorie', and Turbulence Theory. All these theories had their origin in some problem connected with aeroplane movement and ultimately have succeeded in making aeroplanes what they are to-day.

Another field in which models can and have played important part is 'Sub-soil Hydraulics'. Here also theory and experiments have worked together and succeeded in evolving a practical method for the purpose of designing weirs on sand foundations.

The use of models has also been fairly frequent in certain fields of hydraulics. Experiments of Bazin and Darcy on models of falls and weirs are well-known.

In river models M. Fargue, Osborne Reynolds, Vernon-Hercourt and Engel were the pioneers. M. Fargue in France appears to have been the first to construct, in 1875, a model of the river Garonne between Bordeax and the sea, to devise means for training works. Though the scales of the model were such that the scale of distortion, scale of discharge and the time scale were all arbitrarily chosen, the indications shewn by the model were very valuable.

In 1885 Prof. Osborne Reynolds of the University of Manchester instituted a series of model experiments on the upper estuary of the Mersey. The results were so satisfactory that Reynolds concluded his paper with the statement: 'These experiments shewed that the characteristics of the real estuary reproduced themselves in the model after a corresponding number of tides'.

In 1886 Vernon-Hercourt constructed a small tidal model of the estuary of the Seine betweeen Rouen and the sea.

All these experiments by Fargue, Osborne Reynolds and Vernon-Hercourt showed that qualitative agreement could be obtained between the model and the river if sufficient precautions were taken. But quantitative agreement could not be obtained by the experiments as sufficient investigations had not been undertaken to find the effect of the size and density of the bed materials. Before Engels took up these experiments in Germany and Freeman in America, though conviction was gaining ground that small scale river models properly conducted could give valuable indications for training of the river, yet the theoretical backgrounds were not sufficiently clear, nor was sufficient experimental evidence available to base any theory. Since then experimenters in Germany, England and the United States of America have accumulated sufficient experience to build up a working theory.

Theory

The success of a model depends on the truthfulness with which it can reproduce all the conditions of the prototype. A completely successful model is one

that will preserve the geometrical similarity with the prototype, (i.e., it should be an exact miniature copy of the prototype), that will preserve the dynamical similarity with the prototype (i.e., all speeds in the model should be so related to those in the original that all pairs of corresponding forces in model and prototype, whether due to gravity or called into play by the motion, shall be in the same ratio).

Geometrical Similarity

There is a number of problems in hydraulics in which it is possible to preserve both the geometrical and the dynamical similarities in the model. Such are the problems of flow over weirs, spill-ways, undersluices and falls. During recent years much work has been done on such models and the comparison with full scale results shew that if suitable precautions are taken the model gives reliable indications of the behaviour of the original.

Turbulence Criterion

In these models, and as a matter of fact in all models, precautions must be taken not to select the linear scale of the model so small that the resulting movement becomes laminar as the flow in most of the hydraulic problems in which models are used is certainly turbulent. It is well-known that two distinct types of fluid movements are possible. It was first experimentally proved by Reynolds and can also be deduced theoretically that a function of the three hydraulic constants of flow—the average velocity v, a representative length l and the Kinematic viscosity γ = Viscosity/Density—can be framed so that this non-dimensional number called after Reynolds, the Reynolds' Number, $R_e = \frac{lv}{\gamma}$ will completely characterize the fluid movement. The transition from the laminar to the turbulent stage usually occurs at a certain value of the Reynolds' Number, though this value can fluctuate between wide limits depending on the initial conditions of flow. In a pipe this transition occurs usually at a value of the Reynolds' Number

$$R_e = 2100$$

and in canals at $R_e = 525$.

Once the turbulent flow sets in it will persist for all higher values of R_e and then the effect of friction will be less and less felt, and the inertia forces will come to predominate, so that the resistance to flow becomes proportional to v^2, viscosity ceases to have any further modifying effect on the lines of flow away from the boundaries.

It is of course self-evident that movements in these regions of flow are absolutely different so that nowhere in a model should laminar flow take place. So that the first condition is to have the size of the model such that the Reynolds' Number of the model is in the turbulent region. Though it is known from Prandtl and Nikuradses' Experiments that the effect of R_e on the friction coefficient in the turbulent region varies with the increasing value of R_e, from the fact that the Reynolds' Number for the model

is smaller than that of the prototype, the scale effect due to this factor is not very important if the viscous or skin-friction is negligible and the Reynolds' Number for the model itself is high.

Froude's Law

Further effects of friction being practically eliminated from turbulent flow, the fluid can now be treated as perfect and requires only a consideration of gravity. The law that governs this kind of fluid movement with a free surface is known as Froude's Law. This law states that if v_m be the fluid velocity in the model and v_p the corresponding quantity in the prototype then

$$\frac{v_m}{v_p} = \sqrt{\frac{h_m}{h_p}} = \sqrt{\text{laminar scale ratio of the model.}}$$
$$= \sqrt{l}$$

where h_m and h_p are the corresponding distances in the model and the prototype. So that if

$$l = \frac{\text{length in the model}}{\text{length in the prototype}} = \frac{h_m}{h_p}$$

$$\text{then } v = \frac{v_m}{v_p} = \sqrt{l}$$

$$q = \frac{Q_m}{Q_p} = \frac{\text{Discharge in the model}}{\text{Discharge in the prototype}}$$
$$= l^{\frac{5}{2}}$$

Dynamical Similarity

There are many problems in hydraulics in which it is not possible to preserve both the geometrical and dynamical similarities in the models. These problems are mostly concerned with the movement of silt in water. In these problems, as the dynamical standpoint is the more important of the two, very often it is necessary to sacrifice geometrical similarity. Such problems generally occur in river models where to reproduce the depth in the same ratio as the length would either make the model too long for it to be accommodated in the limited space of a laboratory, or the depth in the model would be so small that the velocities would be below the critical values for silt movement and the Reynolds' Number would not be sufficiently high. So that with such models geometrical distortion is adopted in which the vertical scale is different from the horizontal scale ratio. This distortion in the scale gives a steeper slope in the model than in the prototype and helps to make the silt move on the bed of the model. There are various methods for fixing this distortion scale, but it is not necessary to go into details about them here.

The next step is to determine the discharge scale, the silt scale and time scale. Though the discharge scale is provisionally

fixed by Froude's Law, more detailed experiments are necessary to fix it more definitely. Silt in the model should be chosen in such a way that with the distortion provided in the model the silt should start moving in the model at the same stage as it occurs in the prototype. The most difficult point in river model experiments is to fix the scale of time, i.e., to find the length of time for which the model should be run so that certain changes will be reproduced in the model which occurred in a certain time in the prototype. This is an important scale which must be determined before the model can be of any practical use.

Having thus briefly stated the various principles on which river models are now generally run in European and American laboratories, reference will now be made to the development of these model experiments in India within recent years.

Though India is a country of mighty rivers, very little had been done here by way of experiments in laboratories on river models. Only in recent years have some experiments been conducted at the Hydro-dynamic Research Station at Khadakvasla near Poona and at the Punjab Irrigation Research Institute, Lahore.

Experiments with full width model of the Sukkur Barrage

These experiments were conducted at Khadakvasla with a stretch of about three miles of the river Indus at Sukkur in which the full width of the river with Sukkur Barrage and a short distance downstream of the barrage was modelled to a scale of:—

1/300 in the horizontal scale,
1/36 in the vertical scale,

giving a distortion of 8·33. The maximum discharge of the river that was modelled was 507,770 cu./sc. and 355,570 cu./sc. respectively.

These series of experiments on this model were instituted to see how the river will behave after the barrage is constructed and also to see the relative merits of the two systems of river regulation, the open flow and still-pond system. Local silt was injected from time to time and contours of the bed of the river were taken after each run and silt samples were also collected from the Right Bank and Left Bank canals.

Experiments on the river Sutlej upstream of the Islam Weir

A model of the river Sutlej upstream of the Islam Weir at Pallah was constructed in the Hydraulic Laboratory of the Punjab Irrigation Research Institute at Lahore on a scale of:—

1/1000 in the horizontal scale,
1/100 in the vertical scale,

with a distortion of 10.

The river Sutlej at Pallah approaches the Islam Weir at such an angle that part of the approach to the weir between the guide banks is blocked by a high-level hard *bela* (an alluvial deposit

covered over with stubborn plant growth) so that the local officers find it very difficult to feed the right bank canal. The object of these experiments was to devise means for removing this *bela* and for preventing its future formation.

Various devices were tried and the following device seems to be successful in the model. An artificial *bela* 600 ft. long was constructed upstream of the noses of the guide banks. The *bela* was triangular in shape with one side parallel to the Right Guide Bank and the angle between the two sides facing the current was 25°. This had the effect of scouring the old *bela* which was made semi-erodable in the model. It is proposed to try this on a bigger sized model.

Experiments on the Ravi River pocket at the Madhopur Headworks

The experiment on the River Ravi pocket at Madhopur Headworks of the Upper Bari Doab Canal was conducted at the River Model Station at Malikpur of the Punjab Irrigation Research. This model was constructed on a horizontal scale of 1/30 and a vertical scale of 1/10 with a distortion of 3.

There is a considerable entry of big boulders and shingle in the Upper Bari Doab Canal from the River Ravi. The object of this experiment was to devise means for preventing the entry of boulders and shingle into the canal. As quantitative data were not available about boulder and shingle entry in the canal in the prototype, it was not possible to fix rigidly the silt scale. But it was found that the model reproduced faithfully the distribution of shingle varying from a size of 1 inch to 1/5 inch in the various bays of the canal regulator. It was found that a ramp consisting of shingle, boulders and sand and clay forms before the advanced sill of the canal regulator in the prototype and this ramp was responsible for the entry of shingle and boulders into the Canal. Even if this ramp were removed by manual labour it would reform in the next flood season. It was found in the model that by putting in, at the sill level, a platform of a length equivalent to 16 ft. in the prototype all shingle entry in the model canal was stopped. This platform will now be built in the prototype and its effect observed.

Experiment on the Chenab River at Trimmu

The experiment in connection with the Haveli Project of the Chenab River is being carried out at the River Model Station at Malikpur of the Punjab Irrigation Research. This model has been constructed on a scale of 1/300 horizontal and 1/40 vertical with a distortion of 7·5. A total length of the river of about 6 miles, of which about 4 miles is upstream and 2 miles downstream of the proposed weir site, has been modelled in sand. At the upstream end of the model the River Jhelum joins the River Chenab and as the supplies of water and silt in these two rivers are very different both the rivers had to be included in the model.

The object of this experiment is to find how the river will react to the construction of the weir above it. Incidentally the model will show the best position of training works and guide banks so that the approach of the river to the weir may be straight. The maximum discharge for which the model had been prepared is 8·6 cu./sc. which corresponds to 650,000 cu./sc. in the prototype.

Experiment on the Timmu Weir

The experiment on a part of the Timmu Weir including a few bays of the Weir, the left undersluices and the canal regulator is also being carried out at the River Model Station at Malikpur. The model had been constructed on a horizontal scale of 1/50 and a vertical scale of 1/25 with a distortion of 2. It includes a stretch of the river 1½ miles upstream of the weir site and ½ mile downstream. Only the left bank of the river, with the left guide bank, has been included in the model. The object of this experiment is to find :—

(1) the best shape of the weir piers and groynes so that there will be least afflux upstream and least scouring action downstream of the weir;
(2) the length and shape of the guide bank;
(3) distribution of silt in the river pocket and the canal so that methods of controlling silt entry into the canal may be devised.

The model includes only 700 feet width of the weir and a discharge of 171,000 cu./sc. which corresponds to 27 cu./sc. in the model.

(b) The Rise of the Sub-Soil Water Table with the introduction of irrigation.

In the Punjab, the development of an irrigation system is invariably followed by a rise of the water-table. During recent years investigations have been conducted to determine the causes of this rise so that measures might be taken to control it.

The data used in these investigations have been collected over a long series of years and consist of well-levels, taken in June and October, rainfall in the irrigated areas, canal and river discharges and measurements of seepage from canals.

The sources and the methods of abstraction and reduction of the data have been described in Memoirs of the Irrigation Research Institute, Lahore. A brief summary of these is given here.

Well-levels

The wells under observation are situated about 5 miles apart on lines running at right angles to the general slope of the Doab. The distance between observation wells on a line is approximately 4 miles. The observation wells are fitted with measuring plates. Readings are taken twice a year, in June and October, of the depth to the spring level

below the natural surface. In the case of the Upper Chenab Canal the records are available from June, 1907, in the registers now maintained by the Drainage Circle.

The June readings are preceded by several months of low rainfall, and must therefore correspond to a more stable condition of the water-table than those of October, which are taken just after the monsoon rains. The monsoon rains usually start in July, end in September, and are variable in amount. In the following investigation both sets of readings have been utilised, though the regression curve is calculated only on June readings. The reason of this differentiation lies in the fact that the difference between successive June readings is more likely to give a true index of the permanent annual rise than the difference between the October readings, which must be influenced by the monsoon immediately preceding.

Rainfall

There are rain-guage stations in the areas commanded by the canals. These are read daily and a record thereof is kept in the Circle Offices.

Irrigation

Discharges of the canals are observed daily. From these and the water consumption diagrams in the annual blue books, which are used as a check, the amount of water utilized and absorbed per day in the gross area commanded by the canals is obtained.

Areas

The figures for the gross areas commanded in the various years are taken from the blue books.

The methods employed in reduction of the above data for calculating a regression curve are the following :—

(a) *Rise in spring-level.*—This is obtained from each well, by taking the difference between the successive June readings. The wells are then weighted according to the area represented by each. Their weighted mean is taken as the average rise over the gross commanded area in the given year. This is the change in depth or 'Δd'.

(b) *Rainfall.*—As only eleven of the sixteen rain-gauge stations had a long continuous record, these were selected for examination. The readings of each of these eleven rain-gauge stations are calculated for successive five-day periods. The area represented by each station is ascertained by drawing rainfall contours, and the ratio of this area to the gross area commanded is taken as the corresponding weight. The weighted means when calculated give 73 values for the average rainfall in successive five-day periods in each year.

(c) *Irrigation.*—The daily discharges utilized are summed for each of the five-day periods and the totals are

divided by the gross commanded area and multiplied by a factor to give the depth in inches of the five-day irrigation load. As the irrigated area lies more or less in a chess board fashion over the gross commanded area, the assumption involved in the above calculation, viz. that the water utilized is spread uniformly over the gross commanded area, is seen to be reasonable.

(*d*) *Slow Changes.*—The movement of the water-table in any one year has two components. One is a long period movement probably due to the cumulative effect of rainfall and irrigation loads in the past. The second is the short period or annual movement which results from the fluctuations from the mean quantity of water added to the water-table in a given year. The former is known as the ' Slow Change '.

It is difficult to separate the two components of water-table movement except by making some mathematical or physical hypothesis as to the nature of the slow changes. Fisher in 1922 originated the polynomial method, which assumed that the slow changes varied with time so as to be expressible as the sum of a limited number of terms involving ascending powers of time as a variable. This method is very useful but has the weakness that it gives too much prominence to the end points.

The second method is based on a physical law, which assumes that the changes in the water profile of a tract subjected to an increased water-load must follow an exponential series. This fits most of the data with considerable accuracy but cannot bring out the effect of a succession of dry years, for the reason that they should show up as a negative term in the slow changes and the exponential terms can never become negative.

Yet another hypothesis was put forward by Mr. Wilsdon in a communication to the Irrigation Department in 1931. He modified the exponential method, introducing a new term varying with the rate of rise. But this method is also handicapped by the same disability as to the negative terms.

For the investigation of the Upper Chenab Canal the polynomial method has been adopted.

The five-day values of Irrigation (I), and Rainfall (R), are then further reduced so as to give the distribution variates '$a \ldots . f$' in each case. The methods used in this portion of the work have been given by Wilsdon and Sarathy.

The values of Δd, after correcting for slow changes, are correlated with the distribution variates for rainfall and irrigation

separately. The indices M (Multiple Correlation), A (Percentage Variance) and P (Probability of Random Sampling) are evaluated in the usual manner; and the mean monthly regressions are then computed, giving the regression curves of d on rainfall and irrigation separately.

The investigations have shown that the main cause of the additions of water to the water-table is the monsoon rainfall. The correlation between the rise of water-table in the period June to October and the monsoon rainfall is high. The natural October to June fall in water-table can deal with certain additions of water to the water-table, but under present conditions this fall is incapable of dealing with the whole of the monsoon rise except in years of low rainfall.

There appear to be two methods by which it may be possible to prevent the permanent rise of the water-table :—(*a*) the construction of seepage drains to remove water which has been added to the water-table, and (*b*) the prevention of the addition of water to the water-table by taking measures for the rapid surface removal of the rain-water before it has time to enter the soil.

Before a seepage drain can be effective it must cut the sub-soil water-table at the lowest point of its annual cycle of rise and fall. In large areas where the water-table is rising this would necessitate very deep drains which would be extremely costly to construct and maintain. In an area of rising water-table which is not already waterlogged, seepage drains do not appear to be a practical solution. Seepage drains may be a cure for waterlogging, but cannot control the rise of water-table in the pre-waterlogging stage.

The rapid-removal of the rain-water soon after precipitation has occurred appears to be the most feasible method of dealing with the rise of water-table. If storm-water can be rapidly removed from the soil surface by a system of storm water drains it follows that this water will not be added to the water-table. Storm-water drains, since they deal with surface water, need be of no great depth. The cost of construction and maintenance therefore will be small. Following on the construction of these drains, since it has been shown that natural agencies are acting to control the water-table during October to June, it is anticipated that a natural *fall* in the water-table will take place. It has been shown that for every inch of rain removed from the soil surface, a reduction in the rise of 1·5 inches will occur. It seems possible, therefore, that storm-water drains can be constructed to deal with such an amount of surface water that the rise in water-table taking place during June to October may be reduced to such an extent that the natural October to June fall will more than counterbalance this rise. In other words, the removal of storm-water may result, not only in preventing a permanent rise in water-table, but also in securing a fall of the water-table from June to June. The construction of storm-water drains is recommended, therefore, as the method which is likely to

secure most economically the control of the water-table and afford a cure for waterlogging.

(c) The laws of subsoil flow under works on permeable foundations.

The subject of subsoil flow can be divided into three Parts :—

1. Pressure observations on actual works, which failed or are still standing, and the experiments carried out in the field on or near such works to determine the reasons for their failure or stability.

   This may be called the FIELD part of the subject.

2. Observations on models of the works, and other experiments carried out in the laboratory to study the behaviour of the porous medium underlying a weir, when subjected to subsoil flow.

   This may be called the LABORATORY part of the subject.

3. Attempts to analyze the results obtained in (1) and (2) by formulation of empirical or reasoned hypothesis. This may be called the THEORETICAL part of the subject.

Field.—The earliest known pressure observations in India seem to be those for Narora weir of the Lower Ganges Canal in which pressure pipes were inserted.

The pipes were fixed on 27th March, 1898 [1], and three days later there was a breach in the weir.

The pipes were actually read only on the day preceding the failure [2].

In 1916 some extensive observations were taken (by the Executive Engineer, Balloki, now Sir J. B. G. Smith, retired Chief Engineer) on pressure pipes in the Balloki weir floor to find if the floor as existing at that time was safe against uplift [3]. Some of these pipes are being observed even now.

The only known case of field experimentation is that of Dugri I and Jauryan siphons on the Upper Chenab Canal, which were studied by Khosla from 1926 to 1929. These siphons had been giving trouble and Khosla studied the concentration of flow near the toe of the impervious floors by inserting pressure pipes at points downstream of the toe, and by driving them to various

[1] Khosla, A. N.—'Stability of weirs and canal works.' *Proceedings of the Punjab Engineering Congress*, XVIII, pp. 195-196, (1930).

[2] Lane, E. W.—'Security from seepage under masonry dams on sand foundations.' *Proc. Amer. Soc. C. E.*, p. 1237, (1934).

[3] Khosla, A. N.—'Stability of weirs and canal works.' Paper No. 142, *Proceedings of the Punjab Engineering Congress*, XVIII, p. 212*a*, (1930).

depths after certain intervals. He also inserted pipes under the floors and observed the pressures recorded by them [1].

Pressure observations, which subsequently proved of great interest were obtained from Panjnad weir of the Sutlej Valley Project. The pipes were inserted in the year 1930–31, and the first series of observations started on 18-4-1932, the third and final series being completed on 11-1-33 [2].

Pressure pipes were inserted in various bays of the Khanki weir by the late Mr. H. W. Nicholson, before the flood season of 1932 (as a preliminary to the reconstruction which was carried out in 1934 and 1935). Serious damage to some of the bays of the weir was caused by 'piping' in July and August, 1932, and the conclusion was confirmed by the pressure pipes, which showed practically no resistance below the crest [3].

More recently pipes were inserted in the Islam weir of the Sutlej Valley Project to study the causes of the formation of the springs below the weir. The first readings were taken during the cold weather of 1936 and are being continued.

The other weirs in the Punjab which are equipped with pipes are Sulemanki and Marala. Sulemanki is however reported to have a clay substratum into which the piles have been driven [4], and the pressure observations are of little more than local interest. Marala was fitted at the time of its recent reconstruction in 1936.

The cases of weirs for which no pressure observations are available—whether they did or did not fail—have not been included, as while valuable evidence can be obtained on isolated points, the help given thereby to the general development of the subject is meagre.

Experiments.—The experimental work had divided itself into two branches. The first one deals, by means of small size hydraulic or electric models, with the measurement of uplift pressures at various points of the structure and of pressures at points in the underlying porous medium. The second includes large or small scale experiments on the velocities of subsoil flow and is connected with the stability of the sand through which the flow takes place.

Both the branches have a common basis, where the tracing of the lines of subsoil flow is concerned, in that the concentration or dispersion of these lines is believed to give a measure (visual or otherwise) of the changes both in pressure and velocity.

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[1] Khosla, A. N.—'Hydraulic gradients in subsoil water flow in relation to stability of structures resting on saturated soils.' Paper No. 138, *Proceedings of the Punjab Engineering Congress*, XVIII, pp. 140-141, (1930).

[2] Khosla, A. N.—'Pressure pipe observations at Panjnad weir.' Paper No. 162. *Proceedings of the Punjab Engineering Congress*, XXI, pp. 52–54, (1933).

[3] Khosla, A. N.—'Reconstruction of the Khanki weir.' Paper No. 195, *Proceedings of the Punjab Engineering Congress*, XXIV, p. 109, (1936).

[4] Kanwarsain.—*Discussion on P. E. C. Paper No.* 142. (See Reference 3, p. 535, page 212*b*, 1930.)

Hydraulic Models

(i) *Lines of Flow.*—Rehbock, about the year 1929, seems to have been the first to attempt to obtain these lines by allowing aniline dyes to flow from one side of the model to the other. Three photographs of the lines obtained by him were included as an appendix to *P.E.C.* paper No. 162 (see Reference 2, p. 536) and a fourth showing the lines for a floor with equal piles at heel and toe is also given in another paper[1]. All these show a certain amount of dye diffusion.

Mckenzie Taylor and Uppal[2] developed a superior technique. They saturated the subsoil sand with a solution of potassium chromate and introduced, at selected points along the upstream sand layer, a number of pipes through which a solution of silver nitrate could flow into the medium. The interaction of the two chemicals left a red precipitate of silver chromate along the lines of flow, which could be seen and photographed from the glass front of the experimental tank in which the model was placed. By gradual improvement of the method, very sharp lines were obtained.

By this method they traced the lines of flow round floors having the following types of foundation profile[3] :—

(i) Horizontal floor, (ii) Vertical sheet pile, (iii) Semi-circular base, (iv) No. i with an upstream pile, (v) No. i with upstream and downstream piles, (vi) No. iv with an upstream apron, (vii) No. v with upstream and downstream aprons, (viii) No. i with coarse foundation material, (ix) No. i with defective contact at heel, (x) No. i with downstream piles, (xi) No. v with piles reversed, (xii) No. i with pressure relief pipes, (xiii) No. v with pressure relief pipes.

Later they traced the lines of flow under Bays II and IV of the Khanki weir[4,5], and under a number of other models of actual weirs.

More recently Uppal and Mushtaq Ahmad[6] have developed an apparatus in which a thin celluloid model of the work is inserted

[1] Rehbock, Th. Von.—'Sicherwasserbewegung im Erdreich.' *Proc. Int. Commission on High Dams*, V, p. 56, (1933).

[2] Mckenzie Taylor, E. and Uppal, H. L.—'A Study of the flow of water under works on sand foundations by means of models.' *Proceedings of the Punjab Engineering Congress*, XXII, pp. 51–78, (1934). (Reprinted as Punjab Irrigation Research Institute Publication, Vol. II, No. 3.)

[3] The last three forms are described in a second part of Reference 9, *supra*, issued as an Irrigation Research Publication, Vol. II, No. 4.

[4] Mckenzie Taylor, E., and Uppal, H. L.—'An investigation of the flow of water under Khanki weir and the pressures on the floor.' *Research Publication*, II, No. 6, figs. xiii, xix, (1934).

[5] Khosla, A. N., Mckenzie Taylor, E. and Uppal, H. L.—'An investigation of the uplift pressure on a model of Bay IV, Khanki weir and the prototype.' *Research Publication*, II, No. 10, (1935).

[6] Uppal, H. L. and Mushtaq Ahmad, (unpublished work).

in the capillary space left between the two sides of a miniature tank, and in which potassium permanganate is allowed to flow into a layer of water underlying the model. Diffusion is prevented by the narrowness of the distance between the walls and the absence of sand allows the lines to form very quickly. The lines are very sharp and can be photographed, but they disappear as soon as the flow of potassium permanganate is stopped.

In the *Electrical Models* the lines of flow are not traced directly.

Hydraulic Models

(ii) *Uplift Pressures.*—Colman[1] seems to have been the first to investigate by this method the pressure distributions in a sand medium underlying the model of a dam. He inserted 46 ½″ pipes at various points of the box containing the model and attached them to an equal number of glass tubes from which the level of water was read and the percentage drop of pressure calculated. From these values the equi-pressure lines in the medium were drawn.

Colman took two types of sand :—Sand A, with which he tried (*a*) A simple floor, (*b*) The same floor with piling at the heel, and (*c*) The same floor with piling both at the heel and at the toe. With sand B he made seven experiments, three with different lengths of the floor and four with a given floor length and different lengths of sheet piling.

Gunn and Uppal[2] conducted pressure observations on a small scale (1/50) model of Rasul weir (Lower Jhelum Canal). Twenty-six pipes to measure the pressures were put in the sand before building the model, and the levels of the meniscus in each was read by at cathetometer. Later on, Mckenzie Taylor and Uppal[3] ingeniously adapted their tank for the tracing of lines of flow to pressure observations, by drilling 80–100 holes in the steel plate at the back of the tank corresponding to the points at which the pressure observations were required to be made, and by connecting these to pipes in which the water levels could be read. By dividing the head at any point by the total head, and expressing the result as a percentage, the pressure distribution was known.

With this apparatus they investigated the pressure distributions under (*a*) An ordinary floor[4], (*b*) Floors depressed in sand (three ratios and seven cases)[5], (*c*) Floors with piling at the heel (ten

[1] Colman, J. B. T.—'The action of water under dams.' Paper No. 1356, *Proc. Amer. Soc. C.E.*, LXXX, pp. 421–452, (Dec., 1916)

[2] Gunn, J. P. and Uppal, H. L.—'Investigation of observational methods for models.' *Punjab Irrigation Research Publication*, II, No. 2, (1933).

[3] Mckenzie Taylor, E. and Uppal, H. L.—'An investigation of the pressures on works on sand foundations.' *Punjab Irrigation Research Publication*, II, No. 5, (1934).

[4] See Reference 3, *supra.*

[5] Bose, N. K. and Uppal, H. L.—'Uplift pressures under a depressed floor.' *Punjab Irrigation Research Publication*, II, No. 13, (1936).

ratios)[1], (*d*) Floors with piling at the toe (six ratios)[2], (*e*) Floors with equal piling both at heel an toe (four ratios)[3], and (*f*) the models of a large number of weirs with complicated foundation profiles[4]. Later they investigated the effect on pressure distribution of variations in temperature and depth of silt deposit above a weir for a model of the Panjnad Headworks[5], and obtained very good agreement with the values obtained from the prototype.

Electric Models

The electrical method is based on the supposed analogy of the flow of electricity through conductors to that of water through a porous medium. A non-conducting model of the structure, which is underlain by a conducting salt solution, and which separates two conducting segments (representing the upstream and downstream levels) at unequal potentials is the main component. The equipotential lines are traced by means of a needle or probe from points on the structure out into the medium and are taken as corresponding to the equipressure lines for the prototype. The streamlines can be traced by drawing a freehand curve approximately orthogonal to the equipressure lines.

Pavlovsky[6] states that he proposed this method as far back as 1920, and gives three examples of its application in his 1931 paper. He was followed by Hebert[7], who investigated a number of dams by the electric method. These included Narora and Panjnad, but Hebert was unable to obtain a good agreement between the electric analogy results and those given by hydraulic models or the measurements on the works themselves. In the case of Panjnad, however, Uppal[8] obtained a very close agree-

[1] Bose, N. K. and Uppal, H. L.—' Influence of an upstream sheet pile on the uplift pressure on a floor.' *Punjab Irrigation Research Publication*, II, No. 9, (1935).

[2] Bose, N. K. and Uppal, H. L.—' The effect of an end sheet pile on the pressure distribution under a weir floor and on the exit gradient.' *Punjab Irrigation Research Publication*, II, No. 14, (1936).

[3] Results not yet published.

[4] See References 4, 5, p. 537.—A number of investigations are still unpublished.

[5] Uppal, H. L.—' Pressures under a model of the Panjnad weir and under the prototype.' Paper No. 185, *Proceedings, Punjab Engineering Congress*, XXIII, pp. 129–134, (1935). (Reprinted as Research Publication, Vol. II, No. 11.)

[6] Pavlovsky, N. N.—' Motion of water under dams.' (Paper signed on 12th September, 1931, and printed as Report No. 36 of the *Premier Congrès des grands Barrages*, IV, pp. 179–192, which was held at Stockholm in June-July, 1933.)

[7] Hebert, D. J.—' Hydraulic Uplift pressures under dams on previous foundations.' *United States Department of Interior, Bureau of Reclamation*, Technical Memorandum No. 384, (1934). (This reference is quoted on p. 1285 of the *Proc. Amer. Soc. Civil Engineers* for Sept., 1934, in a discussion by Hebert of Lane's paper. See Reference 2, p. 535.)

[8] Reference 5, *supra*.

ment between his model results and those obtained by Hebert previously.

At about the same time Harza [1] obtained by this method the pressure distributions for a depressed floor and for a floor with equal end piles. His work was mentioned by Haigh (F. F.) in introducing his own paper on 'Design of weirs on sand foundations' to the Punjab Engineering Congress held in February, 1935 [2].

Vaidhianathan and Gurdas Ram [3] revived and improved the method in 1935, with which they investigated the cases of (i) A flush floor with no sheet piles, (ii) A flush floor with sheet piles (1 case), (iii) A depressed floor in equal fill (1 case). In a subsequent paper [4] they also treated the case (ii) with a different floor-pile ratio.

Later on they made an exhaustive study of a number of standard forms, which included the following :—

(*a*) Depression floors with and without single end piles [5].
(*b*) Flush floors with and without single end piles [6].
(*c*) Stepped floors with piles at step [7].
(*d*) Floors with equal and unequal end piles, and with equal piles not at ends [8].

More recently Luthra and Vaidhianathan [9] have investigated the case of a flush floor fitted with fixed equal end piles and an inner pile varying in position and length.

A number of existing or proposed foundation profiles were also treated similarly. The results for Haveli (3 separate designs),

[1] Harza, L. F.—'Uplift and seepage under dams on sand foundations. *Proc. Amer. Soc. C.E.*, (Sept., 1934).

[2] Haigh, F. F.—'Design of weirs on sand foundations.' Paper No. 182. *Proc. Punjab Engineering Congress*, XXIII, pp. 115*a*–115*b*, (1935).

[3] Vaidhianathan, V. I. and Gurdas Ram.—'On the electrical method of investigating the uplift pressures under dams and weirs.' *Irrigation Research Publication*, V, No. 4, (1935).

[4] Gurdas Ram, Vaidhianathan, V. I. and Mckenzie Taylor.—'Potential distribution in infinite conductors and uplift pressure on dams.' *Proceedings Indian Academy of Sciences*, II, No. 1, (July, 1935).

[5] Vaidhianathan, V. I., Gurdas Ram and Mckenzie Taylor, E.—'Pressures under weirs—Depressed floors with and without sheet piles.' *Irrigation Research Publication*, V, No. 6, (1935).

[6] Vaidhianathan, V. I., Gurdas Ram and Mckenzie Taylor, E.—'Uplift Pressure on weirs—a floor with a line of sheet piles.' *Proc. Ind. Acad. Sc.*, II, No. 6, (Dec., 1935).

[7] Gurdas Ram and Vaidhianathan, V. I.—'The design of falls with reference to uplift pressure.' *Proc. Ind. Acad. Sc.*, III, No. 4, (April, 1936).

[8] Gurdas Ram and Vaidhianathan, V. I.—'Uplift pressure and design of weirs with two sheet piles.' *Proc. Ind. Acad. Sc.*, IV, No. 2, (August, 1936).

[9] Luthra, H. R. and Vaidhianathan, V. I.—'Uplift pressures under weirs with three sheet piles.' *Proc. Ind. Acad. Sc.*, IV, No. 4, pp. 491–502, (Oct., 1936).

Kalabagh (proposed), and Merala weirs were presented in a paper [1] read before the Punjab Engineering Congress. The rest are not yet published.

(iii) *Velocities of subsoil flow.*—The first known experiments for determining the velocity of water through a horizontal sand layer subjected to a head of water were conducted by D'Arcy [2]. The sand was enclosed between two horizontal parallel planes, whose distance apart was small compared to the length of the sand layer measured parallel to the direction of flow.

His work was followed by that of Hazen [3] who experimented with a number of sands of different sizes and calculated the velocities of flow under varying heads and at different temperatures.

The first experiments, in India were carried out by Clibborn [4], who used a 120′ tube of 2′ diameter, which was packed with Khanki sand and subjected to heads varying from 1′ to 19′. Later he also used Jamrao and Solani sands for other experiments.

Clibborn's object was to determine the velocities of water through different types of sand at different distances from the head of the tube and to find the pressures capable of blowing these sands through the orifices provided at 10′ intervals in the tube. He also arranged for an estimation of the useful effect of a downstream curtain wall in preventing such blowing.

Experiments on the flow of water through different materials were also made by King and Slichter [5], with special reference to the 'porosity'—also known as 'pore space'—of the material.

In recent years the attention of the experimenters has been largely directed towards determining the 'flotation' and 'bursting' gradients, i.e. the ratios of head of water to lengths of sand column (horizontal or vertical) which would cause the sand particles respectively to remain suspended in and to be carried away by the stream of water flowing round them.

1 Vaidhianathan, V. I. and Gurdas Ram.—'Electrical method for determining pressure distribution under hydraulic works.' Paper No. 190. *Proc. Punjab Engineering Congress*, XXIV, pp. 49–53, (1936).

2 D'Arcy, H. (1856).—(There are several papers quoted in various reference books and papers. The best known is 'Les Fontaines Publiques de la Ville de Dijon'.)

3 Hazen, A. (1892).—'Some Physical properties of sands and gravels.' Report of Massachussets Board of Health. (Reference taken from p. 322 of Buckley's Irrigation Pocket book, 2nd edition, 1911.)

4 Clibborn, J. (1896).—'Experiments made on the passage of water through the sand of the Chenab river from the Khanki weir site—May. 1896.' Roorkee Treatise on Civil Engineering—Irrigation Work in India. Appendix D. xxv–xxxviii. (The book was written in 1901. The pages refer to 1909 edition.)

5 Slichter, C. S.—'The motions of underground waters.' *U.S. Geological Survey water supply and Irrigation Paper*, No. 67, (1902). (Reference taken from page 324 of Buckley's Irrigation Pocket-book. See Reference 3, *supra*.)

Terzaghi's [1,2], work in this direction has been followed by that of Vaidhianathan and Luthra [3], who examined the 'flotation' and 'blowing' gradients for twelve specimens of silt and discussed these in relation to the conditions of flow near the toe of a work.

Theoretical.—The theoretical work can be subdivided into :—

1. Empirical :—
   (i) Formulæ or deductions based on experiments or observations.
   (ii) Hypotheses or suggestions, for which the experimental basis is not traceable.
2. Mathematical :—
   (i) Deductions made by the application of hydrodynamical theory.
   (ii) Isolated attempts at approximations.

Empirical

D'Arcy [4] and Dupuis concluded from their experiments that the *velocity of water flowing in minute channels, varied directly as the head* and might be expressed by the equation $v = ki$, in which v is the velocity of flow, i the fall in a given distance divided by that distance, and k a coefficient which varied with the size of the grains of the soil.

Hazen[5] retained the form of D'Arcy's hypothesis, and expressed k in terms of the temperature of the water, and the 'effective size' of the particles constituting the sand through which the water flowed (the effective size being the diameter of the particle, which was exceeded by 90% of these present in the given sand.)

Slichter [6] introduced the conception of 'porosity' into Hazen's formula, while Baldwin-Wiseman [7] gave a very elaborate expression for k, which he deduced from certain experimental data in his possession.

[1] Terzaghi, Charles, (1929).—'Effect of minor Geologic details on the safety of dams.' *Amer. Inst. Mining and Metallurgical Engineers' Technical Publication No.* 215. (Reference taken from page 1293 of Proc. Am. Soc. C.E., for Sept., 1934.)

[2] Terzaghi, Charles, (1922).—'Der Grundbruch an Staumauern und seine Verhütung.' Die Wasserkraft. (Reference taken from page 1290 of Proc. Amer. Soc. C.E. for Sept., 1934.)

[3] Vaidhianathan, V. I. and Luthra, H. R.—'Floatation gradient for the flow of water through porous strata and its bearing on the stability of foundations.' *Punjab Irrigation Research Publication*, V, No. 5, (1935).

[4] D'Arcy and Dupuis, (1858).—'*Traité*' *de la conduite et de la distribution des Eaux.*' (Reference taken from Buckley's Irrigation Pocket-book, page 321, 2nd edition, 1911.)

[5] See Reference 3, p. 541.

[6] Slichter, C. S.—*Proc. Inst. C.E.*, CLXXXI, p. 127, (1910). (Reference taken from Buckley's Irrigation Pocket book, p. 324.)

[7] Baldwin-Wiseman, W. R.—*Proc. Inst. C.E.*, CLXXXI, p. 39, (1910). (Reference taken from Buckley's Irrigation Pocket Book, p. 326).

Clibborn [1] made a number of interesting deductions from his experiments on Khanki sand. Some of these were :—

(a) An effective pressure of 3 feet of water at any point appears capable of blowing sand out with water.

(b) The value of the 5′ curtain at the end of the tube is marked by the way in which it prevents sand flowing slowly out with the percolation water. Its value (it was used with a 120′ pipe full of sand) may be put as equivalent to 15 feet of extra weir.

(c) The resultant upward pressures of water headed up above a work will act under that work with forces in direct proportion of their distances from the point of application to their points of exit.

In other words, Clibborn assumed the fall of pressure to be linear, though for the vertical cut-off used he used a weightage of 3.

Beresford [2] discussed Clibborn's experiments, but did not regard them as being of great use.

Hutton [3] reading a paper before the Simla Engineering Conference on the pressure observations obtained from Narora weir on the day preceding its failure stated that the path of percolation under the weir seemed to him to follow the line of 'least resistance'. It is not known how he arrived at this conclusion.

Hutton also noticed that the pressure pipes showed higher pressures than those calculated from the formula of linear fall of pressure.

Khosla [4] fitted an empirical logarithmic curve to his observations at Dugri I and Jauryan siphons to show the variations in the head recorded with changes in depth of the strainer point. From this curve which he called the 'loss of head curve' he made two important deductions. The first was that the velocity of flow at any point in the subsoil is directly proportional to the loss of head from the normal surface level at the point, and the second that this velocity increases as the depth decreases.

He also found that an 18′ pile cut off about as much of head as it would if it were a 70′ long horizontal floor [5].

Mckenzie Taylor and Uppal [6] concerned themselves mostly about the form and spacing of the lines of flow. Their most important deductions are given below :—

1. There is no flow (or very little) along the foundation profile of a work.

[1] See Reference 4, p. 541.

[2] Beresford, J. S.—'*Govt. of India Technical paper*, No. 97,' (1902). (Quoted in Reference 2, p. 537, by Mckenzie Taylor and Uppal).

[3] Hutton, C. H. (1913).—(Quoted on page 190 of Bligh's 'The practical design of Irrigation Works' by the editor, F. W. Woods. (3rd edition.)

[4] See Reference 1, p. 536.

[5] See Reference 1, p. 535.

[6] See Reference 2, p. 537.

2. The lines of flow under an impervious floor take the form of semi-ellipses.
3. The velocity of flow of the water is increased as it passes under a pile. The lines of flow show a marked tendency to be thrown off away from the pile, after passing its foot.

From their work on pressure measurements on a simple floor they concluded that [1]—

1. The fall of pressure along the base of an impervious floor does not follow a linear law. There is a large drop of pressure on entrance immediately upstream of the work and a further large drop of pressure on emergence immediately downstream.
2. For any fixed point under a work the percentage drop of pressure is constant for all heads examined.

Similarly conclusions had been drawn by Colman [2]. They may be summarized as below :—

1. For a flush floor, there is a relatively large loss of head at the points where the water enters or leaves the sand. The pressure curve closely resembles the probability curve.
2. Piling at the heel of a dam reduces the pressure and piling at the toe increases it.
3. With sheet piling at the heel, the line of major flow approximates to the shortest distance from the end of the piling to the toe of the structure.

Colman also gave two empirical formulæ for the total upward thrust per unit width of the floor with and without piles at the heel.

Bose [3] made a statistical analysis of the data obtained by Taylor and Uppal for a floor-and-an-upstream-pile combination by fitting an experimental curve to the pressure values at particular points. His deductions were that the foundation profile was not the line of major flow, that the drop of pressure along the outer face of the piles was very much more than that along the inner one and that there was a considerable drop of pressure round the foot of the piles. He followed this work by fitting an empirical formula to the pressure distributions obtained under depressed floors [4].

Gurdas Ram and Vaidhianathan [5] concluded that the best position for piles was at the end of a floor, as they cut off more pressure in that position than in any other position. Luthra and

[1] See Reference 3, p. 538.
[2] See Reference 1, p. 538.
[3] See Reference 1, p. 539.
[4] See Reference 5, p. 538.
[5] See References 6, 8, p. 540.

Vaidhianathan[1] concluded that with a floor fitted with equal end piles, a third sheet was best placed near the centre or the heel according as it was shorter or longer than either of the end sheets of piles.

From their experiments on flotation gradient[2] the same authors concluded that the value of this gradient is very nearly unity for the silts of the types likely to form the foundation material of Punjab weirs.

The results of Gurdas Ram, Luthra and Vaidhianathan's experiments on standard forms were utilized by Khosla to frame his method of Independent Variables[3], where each elementary combination of a floor and sheet pile is treated as a separate entity and the results so obtained are corrected for the influence of the neighbouring entities. The correction is expressed by an empirical formula, which gives a very good fit with the experimental values. The basic idea is that the influence of each element of the structure on the pressure distribution is mainly local.

Clibborn[4] was the first to introduce the word 'creep' into engineering literature. He defined it as 'the underground scour of water caused by the heading up of the water above the weir and the fall in level below in times of a low river and a high demand for irrigation'. He suggested an upstream puddle apron (whose invention he attributed to Col. Western) as a means of lowering the hydraulic gradient. He also thought that a 'sheet-piled terminal at the heel, though primarily a protection to the puddle apron, also tends to reduce the danger of longitudinal creep in an efficient manner'.

This last idea was also adopted by Brown[5], who argued that as '(1) the extension of the impermeable platform upstream of the drop wall decreases the upward pressure on the floor below the drop wall at the same time that it reduces the steepness of the hydraulic gradient and therefore the rate of flow of the percolation water, (2) the extension of the impermeable platform downstream has the disadvantage of increasing the upward pressure on the floor below the drop wall, though the steepness of the hydraulic gradient is favourably affected in the same way as by an upstream extension; therefore (3) *a curtain wall is well placed if upstream of the floor, but badly placed if downstream*, except as a precaution against cutting back and undermining of the floor'.

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1 See Reference 9, p. 540.

2 See Reference 3, p. 542.

3 Khosla, A. N. (1936).—'Working rules and general principles of design.' (This forms chapter X of the C.I.B. Publication 'Design of weirs on sand foundations'.)

4 Clibborn, J. (1901).—'Roorkee Treatise on Civil Engineering Irrigation work in India', Chapter VII 'Works'. Paragraph 14, 'Details of main weir design', pp. 137–141.

5 Brown, Sir Hanbury.—'*Irrigation—Its principles and practice as a branch of engineering*,' p. 122, (1912).

The outstanding empirical hypothesis of 'creep' was, however, formulated two years earlier by Bligh[1]. It will be stated here in his own words.

'The main determining factor in the stability of the sand formation is . . . the enforced length of percolation or the so-called creep of the under current' (para. 4).

'To ensure safety from undermining this length l, must be some multiple of the head H. If $l = C \times H$, then the coefficient C will vary in value with the quality of the sand' (para. 6).

In paragraph 9 he gives the values of C, for different sands whose derivation however is not explained. The values vary from 5 for boulders to 18 for light silt.

'If vertical depressions are placed below the base of the floor, the line of percolation may be forced to follow round these obstructions, and may not, as might be imagined, take the line of least resistance. Thus, *if an impervious line of sheet piling or curtain wall of masonry be inserted below the floor, the line of creep may be measured down one side of the vertical obstruction and up the other side. The added length of creep will thus be twice the depth of the curtain*.' (Para. 19.)

His hypothesis can thus be divided into three parts :—

(*a*) The flow of water is mainly along the foundation profile of the structure.

(*b*) The pressure falls uniformly from point to point along the profile. In other words, the velocity of flow at all points of the profile is the same.

(*c*) The total length of the profile should be obtained by following along both sides of the vertical components and should be large enough to reduce the supposedly uniform velocity to a value less than an assumed critical value depending on the foundation material.

Hutton[2] thought that 'in case of a horizontal floor, held in by two lines of sheet piling, the percolation, instead of creeping down one side and up the other of the upstream piling, then along the floor, and then down and up along the downstream piling, would pass direct from the toe of the upstream piling to that of the downstream piling'. This passage Hutton termed the path of 'least resistance'.

At about the same time Griffith[3] put forward a hypothesis similar to Bligh's.

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[1] Bligh, W. G. (1910).—'The practical design of irrigation works,' pp. 147–151. (The pages refer to the third edition issued in 1927.)

[2] See Reference 3, p. 543.

[3] Griffith, W. M.—'The stability of weir foundations on sand and soil subject to hydrostatic pressure.' *Proc. Inst. C.E.*, CXCVII, Part III, p. 221 (1913-14). (Reference taken from page 1237 from *Proc. Amer. Soc. C.E.* for Sept., 1934.)

Very recently Lane [1] studied a number of cases where dams had failed or were still standing. He put forward the 'weighted-creep method', in which he stated that 'creep along vertical surfaces or surfaces sloping more than 45° with the horizontal will be called "vertical creep" and other surfaces "horizontal creep". The weighted creep distance is the vertical creep plus one-third the horizontal creep'. He proceeded to give values of coefficients for safety on the same lines as Bligh's C-values.

Mathematical

(i) The conversion of Darcy's formula [2] from its *linear form for minute channels* to a *differential form for infinite substratum* may be said to form the starting point of the mathematical treatment of subsoil flow. The necessary logic was furnished by Slichter [3], who, combining the geometry of porespace with the hydrodynamics of a viscous fluid, first verified Darcy's law and then put it in its differential form.

Beresford [4], at about the same date had postulated that the lines of flow round a semicircular profile with an infinite substratum would be semicircles, and had interpreted it as being a proof of the law of linear fall of pressure *for all profiles.*

Forchheimer [5] then applied a well-known example in hydrodynamics to evaluate the equi-pressure and stream-lines for the two elementary cases of a horizontal floor flush with its foundations and a sheet pile in equal fill. This was the beginning of the 'stream-line' theory and of the 'method of confocal conics'.

This method was applied by Parker [6], though wrongly, to the case of a floor having a core wall below the crest. It was used later by Harza [7] and Haigh [8] to develop the criteria for safety of weirs.

The essential basis of the stream-line theory was stated in mathematical language by Johnston [9], and at greater length in non-mathematical language by Haigh [10], who did not, however, go beyond the two elementary cases solved already.

[1] See Reference 2, p. 535.

[2] See Reference 4, p. 542.

[3] Slichter (see Reference 1, p. 541).—(Quoted by Bose in Chapter II of 'the Design of weirs on sand foundations.' Central Board of Irrigation in India Publication.)

[4] Beresford, J. S. (1902).—'Experiments on the passage of water through sand.' Govt. of India Technical Paper No. 97. (Quoted on p. 327 of Buckley's Pocket-book (2nd edition, 1911).)

[5] Forchheimer (1927).—'Zur Grundwasserbewegung nach Isothermischen Kurvenscharen.' (Reference taken from page 4 of Punjab Irrigation Research Publication, Vol. II, No. 13.)

[6] Parker, P. A. M.—'*The control of water.*' (Routledge), pp. 292-293, (1913).

[7] See Reference 1, p. 540, (quoted by Haigh in his paper—Reference 2, p. 540).

[8] See Reference 2, p. 540.

[9] Johnston, J. H.—Discussion on P.E.C. Paper No. 173. *Proceedings Punjab Engineering Congress*, pp. 78*b*-78*c*, (1934).

[10] See Reference 2, p. 540. (Also pp. 78*d*-78*e* of Reference 9, *supra*.)

Pavlovsky[1] solved the case for a single-pile-flush-floor combination, Weaver[2] independently obtained the same solution a year later. Pavlovsky also considered the same case with a finite substratum, but the same solution was obtained independently by Muskat[3].

Bose's[4] solution for a stepped floor and his evaluation of the exit gradient formulæ—whose connection with the critical velocity had been evaluated by Terzaghi[5] and Haigh[6]—brings the mathematical development up to date.

(ii) Of the isolated attempts, Hoffmann's[7] use of Fourier Series and linear equations for a flush floor with equal-end-piles, and Haigh's formulæ[8] for cases of symptomatic flow are known. They are only approximations and do not form part of the 'streamline' Theory.

(d) *Fluming.*

Introduction

It is of the highest importance to the Irrigation Engineers here as well as abroad to design, construct and maintain most economically masonry works such as canal falls and bridges over canals. The amount of money spent over such construction in any project is considerable and their annual maintenance charges form a large item in the recurring charges of such a canal system. Efforts of engineers had been mainly directed to reduce both the cost of construction and maintenance of such hydraulic works on canals. Various methods had been tried to bring about this economy : one of the most successful efforts had been the constriction of waterway of masonry works, i.e. fluming. Some of these designs had worked most successfully necessitating very little maintenance charges while others had failed involving severe damage as a result of unexpectedly heavy hydraulic action in a few cases resulting in the partial destruction of the work.

Due to such unexpected divergent and discordant results of designs based almost on identical principles the Central Board of Irrigation instituted a detailed enquiry about the subject which

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1 See Reference 6, p. 539; pp. 187-188.

2 Weaver, W. (1932).—'Uplift pressure on dams.' *Amer. Jour. Math. Physics*, XI, No. 2, pp. 114–145, (June, 1932).

3 Muskat, M. (1936).—'Seepage flux under dams of extended base width and under coffer dams resting on permeable strata of finite thickness.' Physics (*Journal published by the Amer. Inst. of Physics*, March, 1936, pp. 116–125).

4 Bose, N. K. (1936).—'Mathematical Treatment of flow under weirs with reference to uplift pressures and exit gradients. (This forms chapter VII of the C.I.B. Publication.) 'Design of weirs on sand foundations '.)

5 Terzaghi, Charles (1925).—(Quoted by Vaidhanathan on p. 115 of the *P.E.C. Proceedings* for 1935, during the discussion on Paper No. 173.)

6 See Reference 2, p. 540.

7 Hoffmann, R. (1934).—'Die Wasserwirtschaft, 1, 174' (quoted by Muskat in Reference 3, *supra*).

8 See Reference 2, p. 540; pp. 108–111.

was embodied in a publication of the Board in 1934. In the following the definition and classification of 'flumes' will be the same as were accepted in the above publication.

Definition and Classification

The word 'Fluming' is used by engineers themselves in different connections conveying different significances. A very general definition as suggested in the above note of the Board is as follows :—

'A flumed work is one built in a stream of which the waterway is reduced below the normal. It is necessarily accompanied by an increase in velocity.'

With this broad definition flumes can be divided into two distinct types :

Type I. Flumes with a free water surface under atmospheric pressure, so that the depth of water in the flume could increase or decrease.

Type II. Flumes closed on all sides so that the pressure on the top could vary within limits.

Various forms of Type I will be dealt with here. Type II includes cases of pipes and syphons and will not be considered.

Before the various forms of Type I can be properly classified it is necessary to go into some details about the theory of fluid flow in flumes.

Theory of flow

Theory of flow of water in flumes will be dealt with here from the two-dimensional point of view. This will neglect the effect of cross-currents in the flume and also the effect of friction on the side walls. As a fundamental basis for discussion it will be necessary to accept the two following laws of fluid mechanics :—

1. Law of conservation of energy.
2. Law of conservation of linear momentum.

Law of Conservation of Energy

The Law of Conservation of Energy states that the total energy of flow of a volume of fluid remains constant as it flows along the flume excepting for the loss in energy due to friction. So that the total amount of work that can be obtained from every pound of water passing any point in the fluid, assuming it can fall to the datum level and that no energy is lost, is

$$\left(\frac{p}{w}+\frac{v^2}{2g}+z\right) \text{ ft. lb.}$$

where p is the pressure per sq. foot at the point and w is the weight per cubic foot of the fluid, v is the velocity of flow at the point and z is the height of the point above a datum level. This is known as Bernoulli's General Theorem which states

$$z+\frac{p}{w}+\frac{v^2}{2g} = \text{Constant} \quad .. \qquad .. \quad (1)$$

for each stream line. The constant generally is different from stream line to stream line. But in the case where all the stream lines can be assumed to have started from the same total energy line the constant will be the same for all the stream lines. So that the total energy of unit mass of water at any point consists of :—

(i) Potential Energy, i.e. height above a fixed datum ;
(ii) Depth Energy (or Pressure Energy), i.e. the mean depth D over the bed ;
(iii) Kinetic Energy (or Velocity Energy) $\frac{v^2}{2g}$.

The total energy line can be plotted over the water surface setting off the velocity energy $\frac{v^2}{2g}$ before it. There will generally be a slope in the total energy line which will represent the friction on the bed of the flume. For stable flow the total energy line will be parallel to the water surface and the bed of the flume.

Effect of Curvature

Equation (1) will hold so long as the stream lines are straight and there is no marked curvature in them. If they are curved, an additional term involving the centripetal force due to curvature will have to be introduced. If r be the radius of curvature of the stream line passing through the above point with velocity v then the transversal component of the acceleration (contripetal acceleration) is given by $\frac{v^2}{r}$. So that resolving all the forces normal to the direction of flow we get

$$\frac{1}{\rho}\frac{\partial p}{\partial n}+g\frac{\partial z}{\partial n}=\frac{v^2}{r} \quad .. \quad (2)$$

where n is measured along the normal. It will be possible to integrate this equation in a limited number of cases. But it is apparent that the pressure will rise from the concave side of the stream to the convex side at the rate of $\rho\frac{v^2}{r}$ per unit length of the normal.

Energy of flow

If in Equation (1) the pressure energy (depth energy) and the velocity energy are measured over the bed of the flume then the sum of these two energies is known as the Energy of Flow $= D+\frac{v^2}{2g}$ (3)

Suppose on the bed of our flume a small obstruction is placed (see Fig. 1). Suppose the total discharge in the flume is Q and constant. Let $A_1D_1V_1$ and $A_2D_2V_2$ be corresponding quantities in the two sections AB and CD, where

A = area of cross-section,
V = average velocity of the cross-section,
D = average depth in the cross-section.

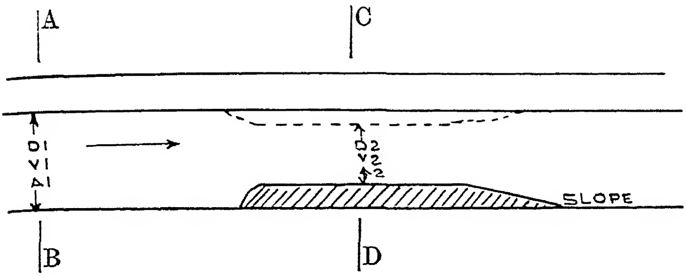

FIG. 1.

Then D is the depth energy,

$\frac{v^2}{2g}$ is the velocity energy.

So that the energy of flow E_f is

$$E_{f_{AB}} : D_1+\frac{V_1^2}{2g} \quad \text{and} \quad E_{f_{CD}} : D_2+\frac{V_2^2}{2g} \quad .. \quad (4)$$

If Q be the total discharge in the flume and B the width of the flume then the discharge per foot width of the flume is given by

$$q = Q/B.$$

In the above Figure constriction had been shewn on the bed alone. It may also be put on the sides changing thereby B and q.

Now in sections AB and CD:

$$V_1 = \frac{q}{D_1}$$

$$V_2 = \frac{q}{D_2}$$

$$E_{f_{AB}} = D_1+\frac{q^2}{2gD_1^2} \quad \text{and} \quad E_{f_{CD}} = D_2+\frac{q}{2gD_2^2} \qquad (5)$$

So that for each value of q a curve can be plotted between E_f and D. Such series of curves are given in the Central Board Publication No. 4, 'Hydraulic Diagrams'. One of these curves is given in Fig. 2.

From Equation (5) it is clear that—

(1) the curve becomes asymptotic to the energy of flow axis for very small values of D;

(2) the curve again approaches the line $E_f = D$ for very high values of D, so that $E_f = D$ is again an asymptote to the curve.

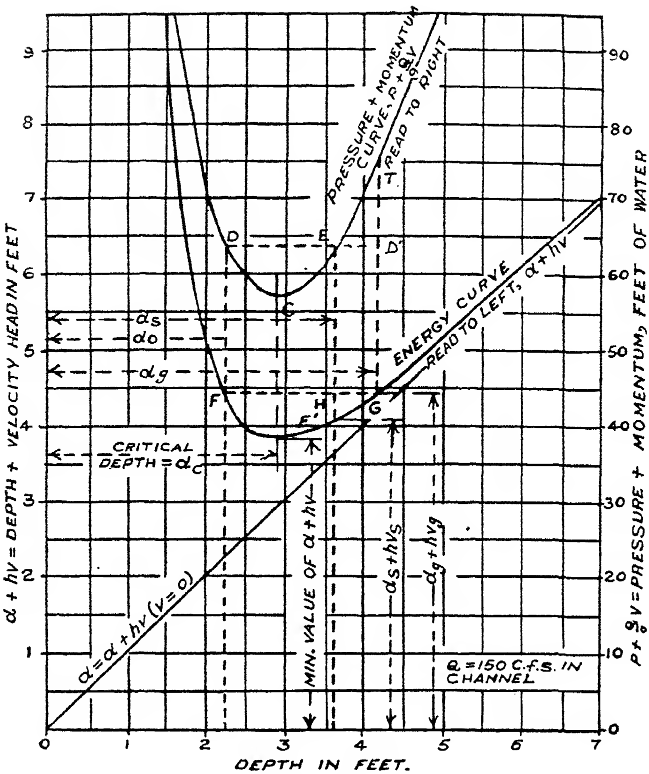

FIG. 2.

On differentiating E_f with respect to D

$$\frac{dE_f}{dD}=1-\frac{q^2}{gD^3}.$$

So that E_f passes through a minimum value when

$$1-\frac{q^2}{gD^3}=0 \text{ or } D^3=\frac{q^2}{g} \text{ or } D=\sqrt[3]{\frac{q^2}{g}}.$$

This depth is known as the ' Critical Depth ' D_C

$$D_C=\sqrt[3]{\frac{q^2}{g}} \qquad \ldots \qquad \ldots \quad (6)$$

The critical velocity V_C corresponding to this depth

$$V_C=\sqrt[3]{gq} \qquad \ldots \qquad \ldots \quad (7)$$

and the energy of flow at this depth is a minimum.

It will be seen from Fig. 2 that corresponding to every value of E_f there are two depths possible of which one will be less than the critical depth and the other more than the critical depth. These two depths are stable whereas at the critical depth where the energy of flow is minimum the flow is unstable. So that if the depth of water before the obstruction is above the critical after passing the critical point, it can either come back to its original state or the velocity may increase beyond its critical value and the depth decrease below its critical point (see Fig. 3).

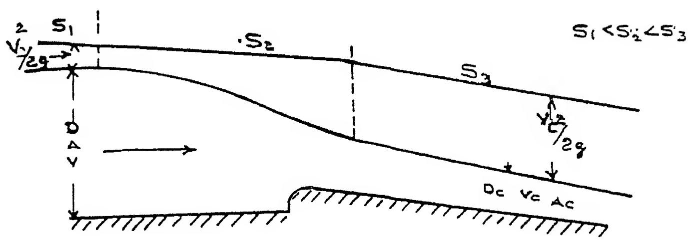

FIG. 3.

Let us reverse the condition now and see what happens. In Fig. 4, the stream is moving with a hyper-critical velocity and there is a gradual rise in the bed. Gradually the velocity is lowered and the depth increased till the critical point is reached and after that the flow becomes normal so that the depth and velocity become such as the slope in the channel can maintain.

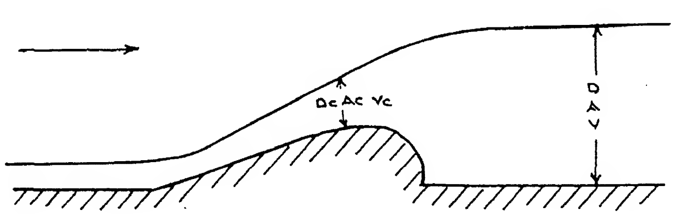

FIG. 4.

If this natural rise in the bed is not available in the flume then the hyper-critical velocity will not maintain itself long but the transition, as given in Fig. 4, will be effected by what is known as the 'Standing Wave'. This is a new phenomenon which is very often utilized in bringing back a hyper-critical jet to ordinary conditions of flow. To explain this phenomenon we shall have to go into details about the second law of flow.

Law of Conservation of Linear Momentum

All moving bodies have momentum. So that every volume of water moving with a certain velocity will possess momentum. According to Newton's Second Law of Motion the rate of change of momentum is proportional to the force acting on the body. So that if we consider the movement of water in the flume across two sections AB and CD (Fig. 5), the momentum across

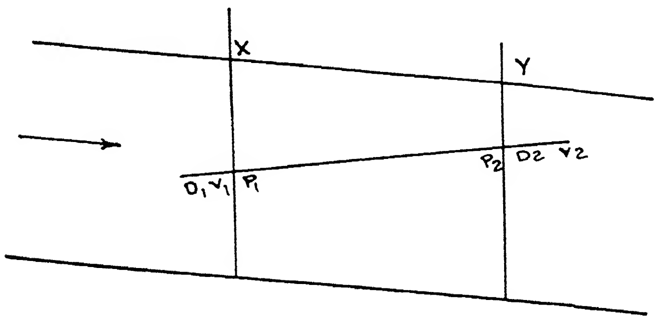

FIG. 5.

the section AB is equal to $\frac{W}{g}QV_1$ and across CD is $\frac{W}{g}QV_2$. So that if P_1 and P_2 be the pressures across the sections—

$$\frac{W}{g}QV_1-\frac{W}{g}QV_2=P_2-P_1+F \qquad .. \quad (8)$$

$$\text{or } \frac{W}{g}QV_1+P_1=\frac{W}{g}QV_2+P_2+F \qquad .. \quad (9)$$

From Equation (8) we find that the difference of momentum across the two sections AB and CD is equal to the difference of pressure on these sections together with the component F of the external forces acting on the prism of water $ABCD$. If the external force be only friction on the bed BD which will be represented by the slope in the T.E. line, so that it can be neglected in Eq. (8) and (9), we get

$$P+\frac{W}{g}QV=\text{Pressure}+\text{Momentum}=\text{Constant} \qquad .. \quad (10)$$

across any section of the flume neglecting friction. Now at any section

$$P=W\frac{D^2}{2}.B.$$

Equation (10) becomes

$$W \cdot \frac{D^2}{2} \cdot B + \frac{W}{g} \cdot q \cdot B \cdot V = \text{Constant}$$

$$\text{or} \qquad D_1^2 + \frac{q}{g} V_1 = \frac{D_2^2}{2} -$$

$$\text{or} \qquad \frac{D_1^2}{2} + \frac{q^2}{g} \cdot \frac{1}{D_1} = \frac{D_2^2}{2} + \frac{q^2}{g} \cdot \frac{1}{D_2}$$

$$\frac{D_1^2}{2} + \frac{D_C^3}{D_1} = \frac{D_2^2}{2} + \frac{D_C^3}{D_2} \qquad \ldots \quad (11)$$

From Equation (11) it is clear that—

(1) the curve becomes asymptotic to the Pressure+Momentum axis for very small values of D;

(2) the curve again approaches the Pressure line for very high values of D, so that the Pressure-Depth line becomes asymptotic to this curve.

This curve is also shown in Fig. 2. There is also a minimum point in this curve which can be obtained by differentiating

$$\frac{D^2}{2} + \frac{D_C^3}{D} = \text{Constant}$$

with respect to D and equating to zero.

$$D - \frac{D_C^3}{D^2} = 0$$

$$\text{or} \qquad D_{\min} = D_C.$$

So that the depth for the minimum point of 'Pressure+Momentum' curve corresponds to that of the minimum point for 'Energy of Flow' curve.

It will be seen from Fig. 2 that the 'Pressure+Momentum' curve and the 'Energy of Flow' curve approach asymptotically the ordinate axis for very small values of D. After the critical point is passed through, both of them approach the Depth-Energy line, the 'Energy of Flow' curve approaches much faster than the Pressure+Momentum curve, so that they diverge from each other after the critical point is passed.

The 'Pressure+Momentum' curve in Fig. 2 has the same abscissæ as that used for the 'Energy of Flow' curve and the values of 'Pressure+Momentum' are shewn on the right. For a given depth there is always one other depth having an equal value of 'Pressure+Momentum', this point falling in all cases beyond the critical depth. Therefore for any depth of flow there is always another depth which we will call the alternative momentum stage

to which the flow may change without the intervention of an external force. Such a change, however, requires a change in the energy of flow.

From Fig. 2 it is clear that for a given change in depth the change in E_f is not proportional to the change in 'Pressure + Momentum' so that it follows that a change in depth cannot occur without the introduction of some factor to preserve balance. A change between alternative energy stages without loss may be effected by the application of an external force only. This can be seen from Fig. 2 where the points F and G refer to the same energy stage where the points D and T having the same depths as F and G refer to a different momentum stage which means that there must have been application of some external force proportional to $D'T$. A change in the alternative momentum stages may be, on the other hand, accomplished by a change in energy only. In Fig. 2 D and E refer to the same momentum stage but the points F and H having the same depths as D and E refer to two different energy stages and the loss of energy in passing from D to E is proportional to $F'H$.

Equation (11) can be re-written in the following form :—

$$D_1D_2\frac{D_1+D_2}{2} = D_C^3 = \frac{q^2}{g} \tag{12}$$

From the above Mr. Crump has deduced the loss of head in the jump as

$$L = \frac{(D_2-D_1)^3}{4D_1D_2} \quad .. \quad .. \tag{13}$$

and also

$$K+F = D_1+C_2\frac{D_C{}^3}{D_1{}^2} \quad .. \tag{14}$$

where K = upstream total head measured over the crest level.
F = elevation of the crest above point of formation of standing wave.

Having briefly dealt with the theory of flow in flumes we can now classify the different forms of Type I Flumes :

Class I. Flumes in which the velocity never rises above the critical.

Class II. Flumes in which the velocity rises above the critical but the design is such that the stream returns to sub-critical flow without the interposition of the standing wave.

Class III. Flumes in which the velocity rises above the critical and in which provision is made for the generation of a standing wave at the point where the stream resumes sub-critical velocity.

Curvature and Curve of Transition

From the definition of 'Fluming' it is apparent that where the flume ends or begins as the waterway in the flume is reduced below the normal there must be a change in the bed level or in the sides of the channel. This is generally effected by giving a gentle transition curve whose radii of curvature is generally determined empirically and is the result of experience. It is apparent that at the beginning and end of a transition, the curvatures should be zero. To determine the intermediate curvature between these points the theory is not sufficiently developed nor is there a sufficient number of experiments to decide the point. It is well known that if the ourve of transition is too abrupt the film of water will not adhere to it but a layer of vortices will form between the film and the curve and the character of the whole movement will change. A number of practical curves of transition with empirical ratios for the splay have been worked out and given in the Publication No. 6 of the Central Board of Irrigation.

In the above, the line followed has been mainly that worked out by Julian Hinds in his publication 'The Hydraulic Jump and critical Depth in the Design of Hydraulic Structures' in the 'Engineering News Record', dated November 25th, 1920, and the paper by A. M. R. Montagu, on 'Energy of Flowing Water, Critical Flow and Standing Waves' in the Punjab Engineering Congress Paper No. 126 and the Publication No. 6 on 'Fluming' by the Central Board of Irrigation.

(e) *Silt in the economy of a Canal System.*

Introduction

One of the main difficulties which Irrigation Engineers in the alluvial countries, such as India, have to encounter is to control silt that is brought down by the canals from the rivers. In spite of very rigid regulations at the headworks the canal engineer finds that his canals are silting up badly and thereby losing command or the berms are falling in rapidly widening the channel and thereby threatening breaches along the line. The amount of money spent on silt clearance and repairs due to silt troubles is considerable on a canal system whose success depends on the degree in which the ill effects of the silt can be overcome or obviated.

1. Every river carries some detritus or foreign substances. In the mountainous region where the slope is steep it may consist of big boulders, shingle and coarse sand. As the river goes down into the plain shingle and boulders become less and less, coarse sand and fine silt predominate, till when it comes near the sea only fine silt can be obtained in the bed and clay in suspension. Nothing is definitely known as to what happens to the shingle

and boulders in the upper reaches and wherefrom do the fine silt and clay come in the lower reaches. Whether this is due to abrasion or any other cause is not material for us; but what is clear is the fact that the coarse sand that is in suspension in the upper reaches is on the bed in the middle reaches and is absent altogether in the lower reaches. So that what is floating silt in one reach is bed silt in another; that is, the line of demarcation between floating silt and bed silt is simply a function of velocity and turbulence. But from our experience in the Punjab canals silt of diameters higher than ·07 mm. is very seldom found in suspension and very little of particles below ·07 mm. diameter size is found on the bed of canals. For the purpose of this article the above definition will be followed.

2. In designing channels it has long been recognized that the silt that the channel will carry can have great influence in determining the ultimate section and slope to which the channel will settle down. This fact was most probably in the mind of Kutter and Ganguillet when they tried to modify the Chezy formula by introducing in the formula a variable factor 'n' which depends on the so-called rugosity of the channels. About 40 years ago Mr. Kennedy of the Punjab Irrigation introduced the idea of silt and turbulence explicitly into the subject and deduced his well-known relationship from about 20 sites on the Upper Bari Doab Canal system. More recently Mr. G. Lacey of the United Provinces Irrigation Department has again revived the subject and proposed in two papers before the Institution of Civil Engineers, London, a number of relationships involving some of the usual hydraulic constants with a quantity known as the silt factor f. For a number of years recently the Punjab Irrigation Research Institute had been busy in finding the behaviour of silt in régime channels. In a paper before the Punjab Engineering Congress in 1935 the writer put forth the results of this investigation.

3. In tackling the problem of silt in canals there had been two methods of attack. One method had been mainly followed by the above class of research workers who had been principally concerned with finding the quantity and quality of silt that a channel with a certain fixed discharge, slope and section will carry without scouring or silting. Research workers in India had been generally taking into consideration only the quality of silt but not the quantity; while workers in America and China are inclined to take quantity also into account. This may be due to the fact that Indian rivers generally do not carry so much silt as those of China and America. The other class of workers had been mainly concerned with the various methods for exclusion or control of silt entry into the canal system. Though the object of both classes of workers is the same, to run a canal system successfully, yet their methods are different and can be made to supplement each other by judicious adjustment.

It is obvious that once silt has got into the main line of a canal system through its headworks, it must go down the system to the tail end. So that if any control or exclusion is to be practised it must start at the canal regulator in the river pocket. If it is known from the available slope of the country what maximum size of silt the main lines and branches can carry it will be possible to exclude from the system all silts coarser than this size. As the main line goes down distributaries take off from it and knowing the silt carrying capacity of each of these distributaties it may be possible by silt-selective heads to give them just the proportion of silt that they will carry. Thus in controlling silt movement in a canal system the above two methods have to work together; at every step one method supplementing the other. It will be shewn later how it is possible to know what grade of silt a certain channel passing a certain discharge through a certain section and slope will be able to carry. We shall now deal with the various methods of silt-exclusion and silt control that are in practice in India.

4. The fundamental ideas that lie at the root of all silt-excluding and silt-controlling devices are the following:—

(1) The heavier grades of silt roll on the bed of the channel and the maximum diameter of floating silt is of the order 0·07 mm.

(2) Silt is made to roll on the bed or held in suspension due to turbulence in the channel which generally starts at the wetted-perimeter of the channel and is caused by unevenness of the boundary. With a fixed depth and mean velocity, a rough bed will carry more silt than a smooth one, though a smooth bed will be able to transport a heavier grade of silt than a rough one.

(3) The velocity of top water in a channel is much faster than that of the bottom water so that it is much easier to deflect the bottom water than the top water.

Based on the above principles various forms of silt excluders and silt-regulators have been devised. We shall first deal with the silt control at headworks. The proper place to deal with the silt trouble in a canal system is clearly at its head. We shall now describe a few cases of silt regulator at the headworks of some Punjab rivers. One of them is described by Mr. King in his paper on 'Silt Vanes and other devices for excluding and controlling Silt'.

A rough general layout of the Silt-Regulator is given in Fig. 6. By the term Silt-Regulator is meant a device for regulating to a nicety the quantity of silt let into a canal as opposed to a mere Silt Excluder. A Silt-Regulator consists of a settling flume *ABEF* with a smooth bed, say of concrete, the function of which is to cause the heavy silt in the water to drop into the lowest possible layers

of water. This flume is continued past the canal regulator up to the Under-sluices, as *EDCB*; but the portion of it opposite the

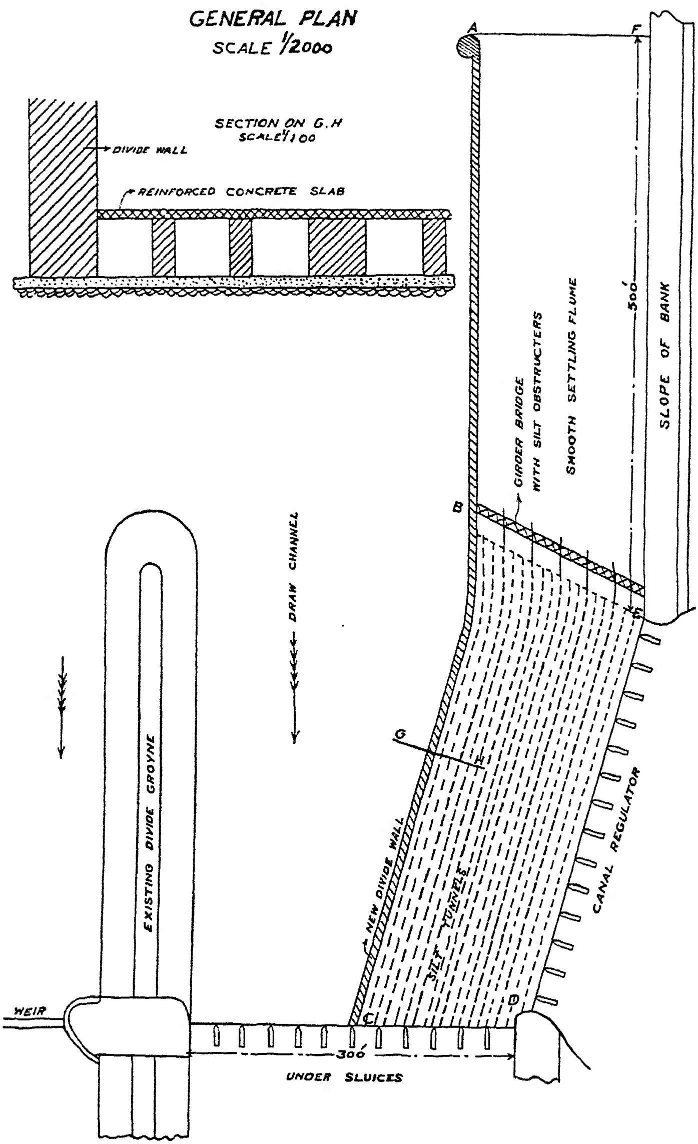

FIG. 6.

regulator is provided with a silt platform, consisting of a slab of reinforced concrete, supported on dwarf walls as shown by the parallel dotted lines, the platform being raised to a height above the floor of the flume by perhaps 5 or 6 feet as may be required.

The space under the platform and between the dwarf walls is called the 'Silt Tunnel'. Just upstream of the 'Silt Tunnels' is constructed a light girder bridge with grooves in its piers into which can be let down 'Silt Raisers' the function of which is by creating obstruction on the bed of the flume to throw up the silt in the lower layers of water towards the surface and thus cause it to be carried over the platform and into the canal instead of under it and into the undersluices.

A modified form of this type of 'Silt Tunnel' had been put in before the lower Chenab Canal regulator in the Chenab River Pocket covering two bays of the Undersluices. This 'Silt Tunnel' was constructed part in 1932-33 and part in 1933-34. This tunnel has definitely reduced the silt charges in the canal. This improvement is reflected in the progressive lowering of the silted bed of the main line and the head reaches of the Upper Gugera Branch to other off-taking channels.

Mr. King suggests a second method of controlling silt entry into canal headworks depending on curved-wing-cum-silt-vanes as shown in Fig. 7. There must be as before a settling flume to cause the silt to drop as low as possible. It is shut off from the main river, as in the case of the Silt Platform or Silt Regulator by a divide wall built to say 5 ft. above maximum supply level.

Three to six hundred feet downstream of the mouth of the settling flume, is built a set of Silt vanes, which terminate, at their downstream ends at the divide wall. The longest vanes should be so placed that it is not closer to the off-take than 50 or 75 feet, depending on the size of the canal.

When it is desired to exclude the maximum amount of silt from the canal, all the silt sluices are of course kept fully open. When it is desired to let a little more silt into the canal the downstream silt sluice is closed.

Mr. F. V. Elsden in his Irrigation Branch Paper (Punjab Irrigation) No. 25 on 'Irrigation Canal Headworks' gives a design for a headworks Regulator.

Coming down the main line from the headworks if it is found that even after the silt exclusion at the head more of the coarser silt is coming than the main line or its branches can carry, a new device of silt ejection is put on the bed of the canal if there is a chance of escaping a part of the bed water back to the river itself. This device had been tried on the Salampur Feeder of the Upper Bari Doab Canal system. This is a modified type of silt-tunnel constructed on the bed of the canal. Above the platform of the tunnel comparatively silt-free water flows unhindered in the main line, while through the opening of the tunnel the bottom silt-laden

water is carried away into the escape. The waterway in the tunnel is so regulated that there is no obstruction to the passage of water.

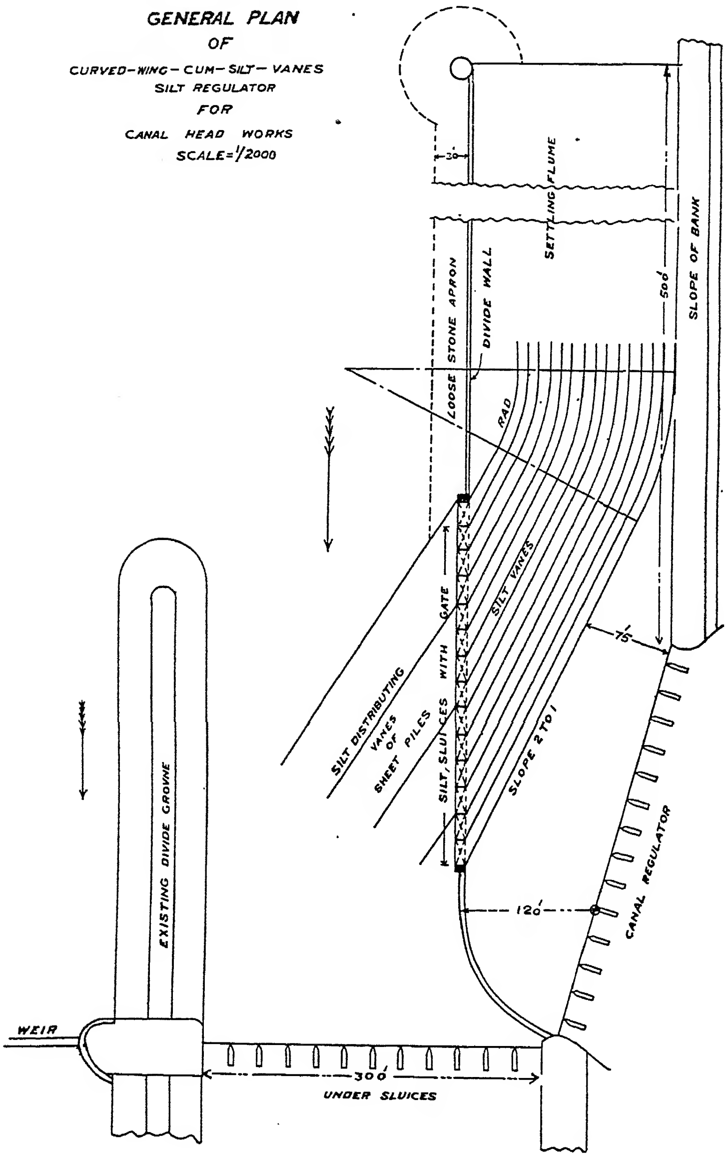

FIG. 7.

As we go further down the main line small distributaries will take off. If the silt carrying capacity of these distributaries be small it will be necessary to exclude further silt. This is effected by various devices such as :—

(a) Silt Vanes.
(b) Curved-wing-cum-silt-vanes.
(c) Silt platform with no guide wing.
(d) Silt platform with guide wing.
(e) Curved wing silt-excluder.
(f) Curved wing with openings.
(g) Raised cill.

It is not necessary to go into further details about these silt excluding devices. Detailed descriptions of these arrangements with their comparative merits and demerits will be found in King's Paper on 'Silt Vanes'. It will suffice to say that a judicious combination of these with proper fixing of their heights and spacing will be necessary to adjust the amount and quality of silt entry into distributaries and minors. It will now be described how we can find beforehand what grade of silt a channel with a certain discharge, slope and section is able to carry.

Researches on the silt carrying capacity of alluvial channels had been carried on by various workers like du Boy, Dupuit and others for very many years. Various formulæ have been evolved by Kennedy, Lacey and others which have proved of immense practical value. But the main difficulty that these investigators had in dealing with this problem was in defining silt. Kennedy in his siltometer proposed an instrument which but for minor defects would have enabled him to classify silt successfully—some of these defects have been since removed by Dr. A. N. Puri and the modified siltometer is being used extensively in the field work in the Punjab. A more accurate siltometer had been evolved by Dr. Vaidhianathan which is being used constantly for silt investigation in the Punjab Irrigation Research Institute.

Mr. Lacey in his paper on 'Stable Channels in Alluvium' proposed a number of formulæ involving the hydraulic data of a channel in régime such as the discharge, the velocity, the wetted perimeter P, the hydraulic mean depth R, the slope s, and a characteristic number f which he says is connected with the silt of the channel. He has also given an empirical relation connecting f with d the diameter of the silt particle in inches.

$$f=8\sqrt{d}.$$

Of the various formulæ proposed by him the following are fundamental :—

$$V = 1{\cdot}1512\sqrt{fR} \qquad .. \qquad .. \quad (1)$$

$$S = \frac{f^{\frac{5}{3}}}{1788Q^{\frac{1}{6}}} \qquad .. \qquad .. \quad (2)$$

$$P_w = 2{\cdot}67Q^{\frac{1}{2}} \qquad \ldots \qquad \ldots \quad (3)$$

and

$$V = 16\sqrt[3]{R^2S} \qquad \ldots \qquad \ldots \quad (4)$$

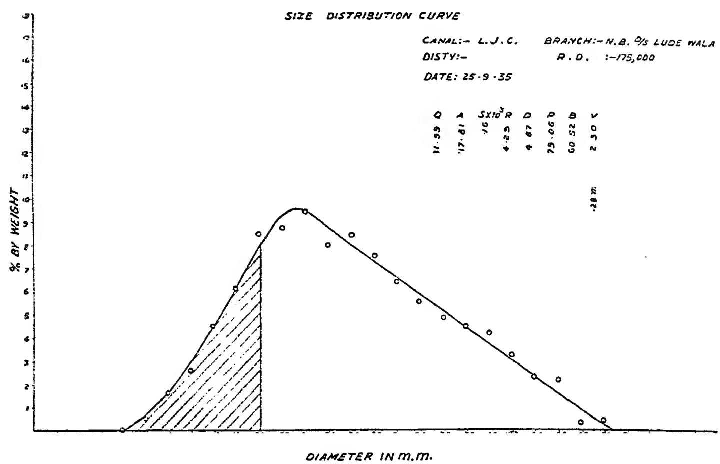

FIG. 8.

These relations have been deduced from a wide range of data of rivers and channels from different parts of the world and carrying different grades of shingle, boulders, and sand.

A direct attack on the problem of silt movement and régime of channels has been carried out by the writer in the Punjab Irrigation Research Institute during the last five years. Hydraulic data and bed-silt samples have been collected in the Research Institute from canal sites all over the Punjab which are known to be in régime. These data and the silt-samples are collected from certain sites daily and from others once a week. These samples are analysed by the siltometer and silt-size distribution curves (Fig. 8) are plotted for every one of them. These curves are very interesting and show the life-history of the channels from day to day. It is possible only by studying these curves (Fig. 9) to find out if a channel is going off régime or not. From each of these curves the average diameters of the bed-silt samples are worked out and it has been proved that this diameter '*m*' is the only quantity that need be considered in order to characterize the silt sample from régime sites. In the subsequent statistical analysis of the problem this quantity '*m*' in mm. has been introduced as a silt-characteristic together with other hydraulic data for these régime sites. The following relationships have been obtained from these data :—

$$S \times 10^3 = 2{\cdot}09 \frac{m^{\cdot 86}}{Q^{\cdot 21}} \quad \ldots \quad \ldots \quad (5)$$

$$\lambda = \frac{R}{P} = \frac{1}{6{\cdot}25} \frac{S^{\frac{1}{4}}}{m} \quad \ldots \quad \ldots \quad (6)$$

$$R = {\cdot}47 \quad \ldots \quad \ldots \quad (7)$$

For redesigning or remodelling a channel it is not very difficult to fix 'f' from Equation (1) or (2) and 'm' from the available silt in the channel itself. But to design a system of new channels where nothing is known as to the silt that is likely to come to the canals from the river, the problem is much more difficult. Enough data are not available to show how m or f varies from the head regulator of any canal system to the tail end. This is a problem which must be solved before the above relationship could be of practical use to project engineers. So that if the project engineer knows what slope he is likely to get in his channel and what discharge is going to run in it, from the above relationships he can work out the value of average silt diameter size which the channel could carry and then by fitting the head of his distributory with silt ejecting platforms or vanes he could get in his channel the required

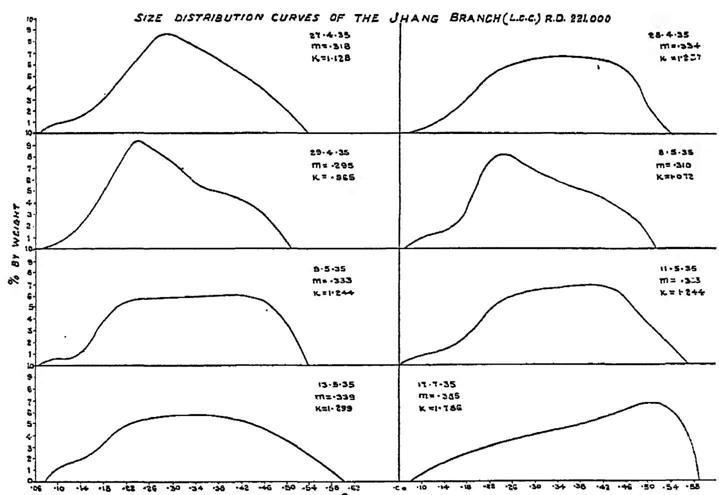

FIG. 9.

grade of silt. So that by a combination of the above two methods of silt control he would be able to run his channel smoothly.

(iii) Marine.

(a) *Tidal Model for the Port of Rangoon.*

Extensive use has been made of working tidal models in the past two decades or so, and as outstanding British examples may be cited those which have been constructed for the investigation of the physical characteristics of the rivers Severn and Mersey. It will be seen from the description, below, kindly sent by Sir Alexander Gibb and Partners, of an experimental tidal model of the Rangoon Approach channels that investigations on a still larger scale and of an equally comprehensive nature have also been carried out in connection with a river, which, when the work was done, ranked as an Indian river. The model was, it is true, constructed and operated in London but the basic data had naturally to be furnished by the Rangoon Port Staff with whom Sir Alexander Gibb and Partners worked in close collaboration.

Rangoon, the capital of Burma, is situated on the Rangoon River 25 miles from its confluence with the Gulf of Martaban. With a yearly export trade of about £5,000,000, it is a most important factor in the Country's trade, and its maintenance for ocean-going vessels is a fundamental requirement for the prosperity of Burma.

The river, which is three miles wide at its mouth, has been subject to periodic change due to the formation and movement of shoals. Continuous erosion of the west bank has occurred just above Elephant Point to a depth of $1\frac{1}{2}$ miles.

The principal problem in maintaining access to the Port is the Outer Bar, an area about six miles wide consisting almost wholly of soft silt. This area has deteriorated from 20 feet of depth in 1884 to 12 feet in 1931 below datum. The tidal rise above datum is 21 feet springs and 12 feet neaps so that a depth of this amount interfered with the traffic of the Port.

It was decided by the Port Commissioners, after discussion with their Consulting Engineers, Sir Alexander Gibb and Partners, London, to construct a tidal model to ascertain the causes of the deterioration and the best means of rectifying the position.

The model was constructed to a horizontal scale of 9 in. to 1 Sea Mile, and 1/16 in. to 1 ft. vertically, an exaggeration of 42 times.

The time scale of the model was 1 : 583, so that the period between successive high tides was 76 seconds. One year occupied about 15 hours running of the model.

The bed of the river and sea was formed of specially selected sand, and by a suitable plunger 15 ft. × 2 ft. actuated by machinery through a system of epicyclic gearing, the varying range of the tide from springs to neaps was reproduced. A small plunger reproduced the diurnal variation at this place.

Fans simulated the Monsoon conditions, and varying flows in the river as between wet and dry seasons were also reproduced

automatically. Silts were introduced into the rivers and sea in correct proportions to agree with the density obtaining under actual conditions. Alum was added to the Sea water in the model to cause an accelerated effect in the settlement of the silt-laden waters of the model necessitated by the exaggerated vertical scale. The over-all size of the model was about 50 ft. × 40 ft.

The model sea bed and rivers were moulded first of all to the chart of 1875, and the model was thereafter operated for over fifty years, up to the condition of 1932 to check that the changes which had occurred at Rangoon were being reproduced in the model. A satisfactory check on this was finally obtained. The model was also run forward to 1982, and finally to 2015, to ascertain what results were likely to occur in future. In addition, tests on Training walls, dredged channels, revetments, etc. were undertaken and analyzed. The operations in connection with the model experiments involved eight separate runs of the model, and the whole of the experimental work occupied three years.

The conclusions reached were :—

(*a*) That the majority of the silt overlying the Outer Bar does not originate from the Rangoon River, but is brought eastward from the mouths of the Irrawaddy.

(*b*) That cyclic changes in the Outer Bar area will always occur and that the condition in 1931 had reached its maximum deterioration, and improved conditions were to be expected in future.

(*c*) The Port of Rangoon will always be accessible to vessels of the size now using it.

(*d*) Artificial works such as training walls and revetments are not justified, and would produce no permanent advantages.

(*e*) A dredged cut, if required, could be carried out and maintained, if properly located to take advantage of the tidal currents.

The consideration of the Report led the Port Commissioners to inform shipping companies that in view of the small proportion of the vessels with large draught which use the Port and which alone would benefit from an expensive dredging programme, they were not prepared to undertake such works. The Port would always be available for vessels up to 28 ft. draught. For vessels exceeding this draught, the Commissioners would not undertake to provide a passage, and the future design of vessels intending to trade to Rangoon should be arranged accordingly.

Actually, since the issue of the Report in 1935, conditions on the Outer Bar region have improved, as indicated by the model, and the ruling depth prevailing is now about 15 feet.

The accurate working of the model was checked by moulding to the 1875 Chart, and after running for a period corresponding

to over 50 years, comparing with the 1932 Chart. After two consecutive checkings giving reasonably correct and comparable results, the Model was set at 1932 and run forward a period of about 50 years, to foreshadow the natural tendencies of the unregulated river. The various possible methods for improving conditions and securing a permanent and adequate approach channel were then tried out in detail.

The principal points in which this Model shows some departure from previous Tidal Models are :—

1. It is believed to be the largest Tidal Model as yet attempted.
2. The propagation of the tides in the estuary at right angles to the outflow of the river.
3. The use of erodible banks. (In previous models banks of rivers and estuaries have been formed of rigid materials).
4. The use of different coloured sands and silts.
5. The special arrangements to produce diurnal variation.
6. The automatic control and variation of upland water as between monsoon and dry weather periods.
7. The variations in silt content as between monsoon and dry weather periods.
8. The automatic variation of the discharge weir in order to maintain a constant mean sea level.

(b) *Tidal Model of Bombay Harbour.*

This model[1] is of special interest as being the only tidal model of any importance which, so far as the compiler of this chapter knows, has been constructed and operated in India.

The model was formed to a horizontal scale of 10 inches to a sea mile and a vertical scale of 1 inch to 8 feet. It reproduced an area of 120 square miles comprised in the Harbour. The scale was such that 9,667 tides could be created in the model in the course of a week's working. The mechanism for propagating the tidal effects gave an accurate rotation of spring and neap tides.

The main object for which the model was constructed was the investigation of a site for a new dock system, but it was also used for other purposes. A proposal had been put forward for the dredging of a large area on the western side of the Harbour. The model indicated, however, that a bar would be formed at the north end of the area which it was proposed to dredge and that this would affect the main channel to the docks. On the strength of this, a definite limit was set to the extent of the dredging operations. There was also a proposal to discharge crude sewage at

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[1] *Proceedings of the Institution of Civil Engineers,* Paper No. 4769 by McClure.

the northern end of Bombay Harbour, in the belief that it would be adequately diluted in the great volume of water contained in the Harbour. The model showed in a convincing manner the cumulative results of the proposed sewage discharge and it brought out the fact that this effect would be specially marked on the commercial side of the Harbour. The scheme was then abandoned. Interesting information was also obtained regarding the distribution of silt in the Harbour.

Although the results so far obtained from this model have been of a negative character, the Port of Bombay has now in its possession a mass of information, obtained from the model, which may be of great value when, at some indefinite date, the expansion of India's foreign trade brings up again the question of an extension of the Bombay docks.

(c) *Model for investigating littoral drift at Vizagapatam.*

The conditions at the entrance to Vizagapatam Harbour were particularly suitable for investigation by means of a working model. It was concluded from inferences drawn from other more or less parallel cases and from observations of the conditions which prevailed at Vizagapatam, that the difficulties which had to be surmounted would arise almost entirely from one source, namely from wave action. Whilst it was true that the wave action was invariably due in the first instance to winds, there was sufficient evidence to show that if the wave action could accurately be reproduced by a mechanism, the subsidiary effects of wind could be ignored. Similarly it was concluded that the effects of tidal currents, which are very feeble on that part of the coast, could be discounted; if the adverse effects of wave action could be countered, then there would be no difficulty in dealing with any sand movements directly caused by tidal currents.

It was also considered that the area of sea in which it was necessary to investigate the physical conditions was a very restricted one. This brought with it the great advantage of its being possible to construct the model to a natural scale instead of having, as is usually the case, different horizontal and vertical scales. Nor was there any necessity to attempt to reproduce the salinity of the water, or its silt content. The problem was exclusive that of investigating the effects of wave action on the outer channel of the Harbour and of deducing the most advantageous position in which to site a Protective Work of the type which has been described in Section II (iv) above.

The model was constructed to reproduce to a scale of 1/100 an area of the sea-bed, roughly 4,500 feet long by 2,500 feet broad. Extensive observations had been made of the direction, height, length and other characteristics of the waves which pass into this area during the South-West Monsoon. The wave action was

induced in the model by a triangular dispacer at the extreme seaward edge of the area in question. Experiments on the travel of the sand were not started until the correct alignment, level, section and stroke of the displacer had been ascertained by trial. The directions of the waves vary appreciably, as a result of diffraction, over the area and it was found possible, after a number of trials, to reproduce these with great exactitude.

The effect of the littoral drift occasioned by the wave action upon a short length of channel, which had been dredged in the previous calm season, was accurately known and this effect, too, was found to be closely reproduced in the model, once the displacer had been accurately sited.

The problem of determining the best alignment for the Protective Work was then attacked. Models of Breakwaters of various types and lengths were successively placed upon the bed of the model and the behaviour of the sand and other phenomena were carefully observed. The alignment, length, shape and position of the Breakwater, as actually constructed, were determined directly from the results of these experiments ; for it was felt that whatever error might be inherent in the model, no surer guidance was in any event available.

A factor of great importance in the situation was the degree of tranquillity which could be produced under the lee of the Breakwater in the area in which dredging operations would have to be carried on. On this point it was felt that the indications given by the model could be accepted with a large degree of assurance ; nor was it eventually found that this confidence had been misplaced.

Whilst the qualitative results given by the model were from the onset believed to be reliable, it must be confessed that the quantitative results were accepted with a certain degree of reserve. Nevertheless, when it became possible, after the Breakwater had been constructed, to compare actual results with those which had been predicted by the model, a close parallel was found. Doubts have been cast on the feasibility of obtaining reliable results by the use of a model such as this in which the sand employed, though of the very finest, reproduced, to actual scale, a mass of small pebbles. However this may be, the fact remains that a very close parallel was established, and it has possibly been overlooked by some that the reaction between the water and the wet sand, both in the model and in the prototype, is that between a comparatively light and a heavy fluid.

It has been stated above that the model was constructed to a natural scale ; nevertheless, there was one factor which as a matter of course was to a different scale, namely that of time. Time passed, as it were, through the model, at an arbitrary pace. The scale of the model was 1/100. The scale of wave velocity was,

therefore, approximately $\sqrt{\frac{1}{100}} = \frac{1}{10}$. In order to reproduce the true wavelength it was, therefore, necessary to propel ten times as many waves across the model as would actually occur in the prototype in the same period. It was consequently possible to reproduce, in a period of twenty-four hours, the effects of the monsoon during a spell of ten days.

(iv) The Stresses in a Steel Structure.

Whilst the stresses in a steel structure can, in the majority of cases, be determined by simple methods with a reasonable degree of accuracy, instances do occur in which, whilst the stresses cannot be said to be indeterminate, the Engineer has the choice between making one or more arbitrary assumptions, and carrying out a most irksome and laborious mathematical analysis.

The little instance given below of the use, in conjunction with each other, of two new methods for the accurate computation of the stresses in a steel structure of a difficult type is of interest to the writer partly on account of the facts that the investigations were carried out by the designer, Mr. G. Wilson, on his behalf and that it fell to him to urge that the conclusions which could be drawn from the two methods of attack be compared before the figures were finally accepted. This personal concern in the case is doubtless insufficient to warrant a reference to it in this connection, but it may be that the matter will excite the interest of other Engineers dealing with similar problems, and this is the sole justification which is now put forward.

The sources of the methods of treatment of the problem are not Indian sources, but it can be claimed that the methods have been brought into juxtaposition in India, and possibly, in view of their recent origin, for the first time. Professor Hardy Cross of the University of Illinois, U.S.A., has recently brought out for such structures as are referred to above, a mathematical treatment which he calls 'The Column Analogy'. It will be gathered from Mr. Wilson's description below that, though really simple, it requires a series of efforts of the imagination. One has to pretend that a structure, subject to stresses acting parallel to a section through it, is really functioning as a column sustaining loads acting in a direction normal to the section. It has also to be supposed that these loads take the form of moments—a state of affairs which is about as easy to visualize as is the fourth dimension. Having thus adjusted one's thoughts, the correct result follows as a matter of course.

Whilst Professor Hardy Cross was engaged upon his theory, two British investigators were obtaining useful results from celluloid

models. The models for use under this method corresponded in general shape to that of the structure under investigation, but the actual sections were determined in relation, not to the sections of the members composing the structure, but to a function of these.

The design of the structure referred to below was arrived at by the first method, but verified by the second method, with results which may be judged from Mr. Wilson's description which follows.

The Turbine House of Messrs. The Calcutta Electric Supply Corporation's New Generating Station at Mulajore will be a steel framed structure; the main building will be 320 feet long by 62 feet wide, between centres of main columns, and it will be flanked by an annexe on each side.

The main columns are spaced at 20 feet centres longitudinally and carry crane girders for a 100 ton and a 15 ton crane in the main building and a 10 ton crane in the eastern annexe; these columns are connected in pairs across their tops by transverse roof girders, which carry north light roof trusses: the roof itself consists of a reinforced concrete slab resting on steel purlins carried on these trusses: the walls of the building are of brick and are carried on steel beams framed into the structure. The structure is 71′ 3″ high from the column baseplates to the centre line of the roof girders which are 10 feet deep.

The basic assumption underlying the design is that the main columns and roof girders form a series of portal frames the columns of which are fixed at the base, and that these resist all lateral loads: the columns in the annexes carrying only vertical loads.

The lateral forces considered were those due to the force of the wind and the surge of the cranes.

The maximum wind load is 19·4 tons and the maximum crane surge 14 tons per frame: allowance has, however, been made for the transference of 5 tons of the crane surge to the adjacent frames through horizontal bracing which is provided at the level of the bottom chords of the roof girders: the transfer occurs because the more heavily loaded frame can only deflect more than the adjacent frames by the amount of the lateral stretch in the members of the roof bracing.

The main frames were designed by means of 'The Column Analogy', an exceedingly simple, though mathematically exact method of determining moments in encastré beams, hyperstatic arches and single portals. This method, which is due to Professor Hardy Cross of the University of Illinois, U.S.A., may briefly be described as follows:—

First, consider the intermediate single span plane structure, which is to be designed, and which is subjected to any system of known loads: introduce imaginary hinges or cuts, at such points as will render the frame statically determinate, and draw a curve of moments for the loading in question.

Second, picture a short length of column, a section of which has the same shape as the side elevation of the axis of the indeterminate structure under consideration, and a very small width, i.e., inversely the product of the modulus of elasticity and the moment of inertia of the corresponding cross-section of the structure.

Third, load this imaginary column with an intensity of load equal at any point to the bending moment at the corresponding point of the structure just computed for the imaginary statically determinate condition.

The change in moment at any point of the actual structure due to restraint, i.e. to the removal of the imaginary hinges or cuts, will now equal the fibre stresses which would exist at the corresponding point in the imaginary column.

'The Column Analogy' was used to determine the stresses in the portal frames due to a series of horizontal and vertical loads at various points and the total stresses due to the various combinations of loads were obtained from these by multiplication and tabulation.

A check on the work was obtained by testing an unloaded model, as described recently by Messrs. Pippard and Sparkes in the Journal of the Institution of Civil Engineers. The principle of the unloaded model is that if a known translation or rotation is applied at any support, then the reaction in the direction of the applied translation, or the bending moment, at that support due to any force applied in any direction to any point of the frame is equal to the deflection (in the direction of the force) of the point of application of the force due to the applied translation or rotations divided by the amount of the applied translation or rotation.

The moment of inertia of the cross-section of the model at any point must be proportional to the moment of inertia of the corresponding point of the actual structure.

In this case the model was cut out of celluloid, the axis being set down to a scale of a quarter of an inch to the foot.

The results were most gratifying. In the case of horizontal loads applied at various levels, the bending moments at the bases of the columns obtained from the model checked in every case within 5 per cent. of the values obtained by calculation. In the case of eccentric vertical loads acting at various points the results were not quite as good, but the only serious differences occurred in cases where the load caused a very small bending moment at the base of the column. In such cases, the deflections were small and difficult to measure: also the differences, though relatively large, were absolutely small.

IV. Concluding Note.

The compiler of the chapter wishes to express his deep obligation to his collaborators, who have provided almost the whole of

the matter comprised in this chapter. The descriptions of work done and of investigations carried out have all been furnished by busy engineers, and their contributions have entailed on them a real sacrifice of valuable time. The subjects dealt with are very varied, though it is true that it has not been possible to cover the whole of the ground. There has, too, been great diversity in the framing of the several parts of the Memoir. It is feared that few people will be equally interested in all the topics, but it is hoped that this very diversity, both in the method of presentation and in the subject-matter itself, will make it possible for most readers to find some portion or other which will in a measure accord with their tastes.

PROGRESS OF PHYSIOLOGY IN INDIA DURING THE PAST TWENTY-FIVE YEARS.

By

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Contents.

I. Introduction.

In presenting a brief review of the History of Physiology in India during the last 25 years, attempt has been made to indicate in a general way certain tendencies only amongst the research

workers in this country. It should thus be possible to obtain a general idea of the special fields that are being traversed and the progress made. It is by no means a compendium of the work of all the workers, as it was never hoped to accomplish a task of such magnitude within the limits assigned to this chapter. There must be, therefore, many omissions, for which the author hastens to apologize to the workers concerned.

Physiology has been, in the truest sense, a handmaiden of medicine in this country. It is only lately, that it has been able to claim a more or less independent existence. Amongst the earlier Physiologists, we have had some excellent teachers, such as McCay and Mahalanobis in Calcutta, Moorehead, Meyer and Hutchinson in Bombay, Donovan in Madras and Caleb in Lahore, who organized the teaching of Physiology on sound lines in the Medical Colleges and Universities. The number of workers in this subject during the last 15 years or so has steadily increased and consequently there has been a marked increase in the output of research work. The problems, which have attracted special attention, are those concerned with digestion, metabolism, nutrition, vitamins, blood and the cardio-vascular system. Attempts are also being made to determine normal physiological constants for the inhabitants of the country. This is all to the good. The data so collected will, it is hoped, form the foundation of the science of Anthropological and Tropical Physiology.

Much impetus was given to the study of the subject by the establishment of a separate section of Physiology in the Indian Science Congress in 1936, and by the organization of certain societies, notably the Physiological Society of India, Society of Biological Chemists, India, etc. Certain Medical Colleges also were pioneers in starting Physiological Societies (Bombay and Lucknow). Another noteworthy event is the introduction of pharmacology in the medical curriculum of Indian Universities and for post-graduate studies at the School of Tropical Medicine, Calcutta. Pharmacology is intimately connected to physiology, and the important researches that have been carried out during the last two decades have helped in elucidating many phenomena of interest both to physiology and tropical medicine. The future appears to be very bright, and it is to be hoped, that the science of Physiology in India will make rapid strides in the years to come.

II. Blood.

A large number of investigations have been carried out on the cytology and chemistry of blood.

Chatterji has shown that the two well-known methods of measuring the diameters of red blood corpuscles, viz., by the Camera Lucida and by Halometer give remarkably different results. He lays stress on the estimation of the thickness of these corpuscles

along with their diameter, and the total volume of each corpuscle rather than the diameter alone. Napier and Gupta found it necessary to have accurate measurements of the dimensions of red blood corpuscles. They compared different methods in vogue, e.g., halometric, Price-Jones, etc., and concluded that the packed cell method is, with a few modifications, the most convenient.

Basu, Ghosh and Ghosh have shown that the red blood corpuscles get crenated even in normal saline and enlarge in concentrated saline solution. Basu has made further studies on the subject, and gives an explanation of the phenomenon.

Dhar has carried out hematological studies in non-pregnant healthy Indian (Bengalee) women, between the ages of 16 and 35 years, and has found that the average count of reticulocytes was 0·945% of red cells, the extremes being 2% and 0·3%. Of these estimations 93% were between the range of ·3% to 1·4% which may be considered to be the normal range for Indian women. N. C. Bhattacharya has studied the structure of the human red blood corpuscles.

Chowdhary and Basu have recommended the thick film method for differential leucocyte count in case of leucopenia and extreme anæmia.

D. M. Telang in connection with work on the biophysics and biochemistry of blood in human tuberculosis studied the suspension stability of the blood in normal subjects and in tuberculosis. He concluded that in tuberculosis this test serves only as a negative diagnostic test, but that it is of great value in the prognosis of the disease as well as in following up its progress in a given line of treatment. He also found : (*a*) that both systolic and diastolic blood pressures in tuberculosis are below normal, but that the pulse pressure is not materially altered in the disease, and (*b*) that while the calcium content of blood in tuberculosis is below normal, the sugar, urea and chloride contents are not affected.

Mathur has shown that the percentage of haemoglobin in healthy Indians of Lucknow averages between 75 to 80% of the normal, and that there is a regular rise and fall in this in accordance with the rise and fall of outside temperature. He has also shown that vulture's and fowl's blood resemble each other so far as coagulation is concerned, although vulture is a meat-eater and the fowl a vegetable-eater. The coagulation of blood of both animals is indefinitely delayed, if its plasma protein complex is not allowed to come in contact with tissue fluid, and is hastened if it is agitated with a water-wettable substance or brought in contact with tissue fluids, specially glandular tissues. Thus this peculiar feature of delayed coagulation in birds (fowls and vultures) does not depend upon diets, but on some other factors.

S. M. Bannerji and D. N. Mullik have described a modified Wu's method for micro-estimation of haemoglobin, and have determined the Hb-content of Indian blood by this method.

S. C. Sen and G. N. Bera have studied the coagulation time of the blood of Indians, and of the blood of guinea-pigs and rabbits.

B. B. Sarkar has made observations on the haemostatic properties of ayapin and ayapanin.

Chopra and Mukherjee have shown that the viscosity of blood sera is lowered with increasing concentration of NaCl. Since a change in viscosity of plasma influences the hydrostatic pressure of the circulation and therefore the rates of transudation and exudation of tissue fluids, it becomes obvious why salt free diets would be beneficial in cases of œdema.

S. C. Devdatta and his assistants have found that no direct relation could be traced between the fall in concentration of sugar and the formation of lactic acid in blood, in serum or in corpuscles. Sugar does not disappear completely. Both components, serum and corpuscles are necessary for glycolysis. S. S. Cowlagi has also worked on the subject.

In order to have a better understanding of the various chemical processes taking place in the blood during each respiratory cycle, S. C. Devdatta has studied the ratio of the concentration of lactate in the corpuscles and in plasma. In the case of fatigued animals and subjects, this ratio is lower than that observed in resting animals and subjects. This change in ratio is not due to a delay in the diffusion of the lactate from the plasma into the corpuscles, nor to the presence of some indiffusible substances estimated as lactate in the corpuscles or plasma. This ratio is found to be raised by increased partial pressure of carbon dioxide or by decreased partial pressure of oxygen or by increased hydrogen-ion concentration. These facts lead to the conclusion that the 'lactate shift' is analogous to the 'chloride shift', and occurs during each respiratory cycle in the blood, which may become of importance in connection with the buffering of the blood in conditions of oxygen debt. The same author has investigated the ratio of the concentration of lactate in the corpuscles and in the plasma in the blood of pernicious anæmia patients, wherein he finds that the ratio is more than unity which shows that the concentration of lactate is higher in corpuscles than in plasma. This may be attributed to the higher content of haemoglobin in the cells.

Charles Reid and B. Narayana have found that starvation decreases and the administration of food increases the rate of glycolysis in blood. They say, that the factors responsible for glycolysis in blood are present in both erythrocytes and serum. The same authors in their '*Studies in Blood Diastase*' find that the blood diastase decreases after meals, injections of glucose, glycogen and insulin, while anæsthetics and injections of starch cause a slight increase. Since pancreatectomy causes little or no change in the amount of circulating diastase, the pancreas is not the main source of blood diastase. Ligature of pancreatic duct does not result in any striking change in the diastase content of the blood

in the course of one or two weeks. Since definite variations can be induced in the blood diastase by injections of insulin, glycogen, etc., it appears likely that the circulating diastase is not entirely a waste product on its way to excretion. Evidence is adduced that the variations in blood diastase are probably due to its being taken up or given out by the liver cells, etc., according to the requirements of the body with respect to the glycogen-glucose equilibrium probably in association with insulin.

Hughes and his co-workers found that serum calcium in normal Punjabi is higher than the normal residents in temperate climate. Oral administration of Vitamins A and D produces changes in serum calcium and plasma cholesterol. Cases of osteomalacia treated with Vitamin D were found to recover slowly but the addition of Vitamin A caused a quicker rise in serum calcium and also recovery of patients.

Sen and Chowdhury have shown that glucose injections increase the calcium-content of blood, although adrenaline injection, which brings about increase of blood sugar, does not cause an increase in calcium-content. Adrenaline injection following sugar injection causes a great rise in sugar content of blood without causing an increase in calcium-content. Further, if adrenaline be injected after the calcium-content of blood is raised by glucose injection, the curve of calcium in blood gradually comes down to normal. If glucose be injected after adrenaline no change of the calcium-content takes place.

Hughes and Malik found initial blood sugar abnormally high in patients suffering from diseases other than diabetes and endocrine disturbances. Derangement of glycogenic function of the liver due to previous history of malaria is suspected.

Chopra and Bose, and Chopra, Bose and De found that opium in small doses had no influence on the blood sugar of normal individuals or patients suffering from Nephritis or diabetes.

Basu reports that injection of emetine in rabbits and rats causes an increase in blood sugar by stimulating vagus nerves.

S. Prasad and B. B. Sen found that Evipan Sodium in anæsthetic doses raises the blood sugar of the rabbit.

B. N. Chatterjee has studied the effect of iron on hæmogenic organs and finds that the administration of moderate doses of Ferri-et Ammon. citras (green) in normal puppies does not alter the blood picture as far as the leucocytes are concerned. In most cases a definite increase of reticular normocytes has been noted towards the end of the period of iron administration. There is an increased activity of red blood cell forming organs like spleen and bone marrow as results of iron treatment.

R. N. Chopra has made observations on the *hæmolysis* caused by snake venoms, and finds that passing the venom solutions (Cobra and Russel's viper) through the Seitz filter renders them non-hæmolytic, that the Seitz-filtrate of venom solutions are not reacti-

vated by lecithin. In the filtrate from cobra venom solutions the vascular effect is altogether absent, the respiratory effect being only slightly effected, whereas in the case of Russell's viper venom, filtrate through a Seitz filter has a marked effect on both these properties.

Sen in his researches on hæmolysis finds that normal serum can act as hæmolytic as well as anti-hæmolytic agent depending upon circumstances. The effect on serum can be initiated by substances which give hydroxyl ions.

Sen and Roy have shown that methyl-, ethyl- and diethyl-amines, piperidine and ammonia cause acceleration or inhibition of hæmolysis depending upon whether they are added with or after sensitizers. N. M. Basu and B. P. Datta have made observations on Ponder's method of determining percentage hæmolysis of blood caused by various hæmolytic agents.

Biswas has studied the influence of antibody formation of the pseudo-globulin fraction of normal serum and notices that the anti-serum pseudo-globulin absorbs the H-ions of oxalic acid less effectively than normal serum pseudo-globulin. Further, anti-serum pseudoglobulin absorbs OH-ions from NaOH solution in the same way as normal serum pseudo-globulin does. In the case of titration with Na_2CO_3 and oxalic acid, the anti-serum pseudo-globulin behaves in a different way from normal serum-pseudo-globulin.

Boyd and Roy reported a definite increase in the *cholesterol* content in blood in Filaria, the average increase being 0·146% as against the normal average of 0·116%. Hughes and his co-workers observed that in osteomalacia, there is low plasma cholesterol. Improvement in the clinical condition on treatment with Vitamins A and D and calcium glycerophosphate is associated with a rise in cholesterol content. Ghosh determined the cholesterol content of a large number of normal and pathological blood specimens in Indians. He discusses the significance of blood cholesterol in jaundice, and finds that the cholesterol content of blood of Indians is about 40 mgms. per cent less than the European and American standards.

Sankaran reports that uric acid was present in about 30 times the normal concentration in the blood plasma of a fowl kept on Vitamin A deficient diet for 12 weeks. The excess of uric acid in blood was not directly due to Vitamin A deficiency, but was caused by a pyrophoresis consequent on Vitamin A deficiency.

S. N. Ray and R. Ganguly have found that the iron and copper contents of the blood of normal Bengali subjects are 39·0 mg. and 0·14 mg. per 100 c.c. respectively.

S. S. Sokhey, S. K. Gokhale, M. A. Malandkar, and H. S. Billimoria have worked out the standards for the normal averages by the study of bloods of 121 healthy young men from the Bombay Presidency between the ages of 19 and 30 years. They have used the Van Slyke oxygen capacity method for the deter-

mination of hæmoglobin. Their average hæmoglobin figure agrees with that of two other series examined in America in which hæmoglobin was determined by the Van Slyke's method. They have studied the shrinkage of cells in blood caused by the use of potassium oxalate. They have also recommended for clinical work an accurate alternative calorimetric method to Van Slyke's oxygen capacity method for hæmoglobin determination.

S. S. Sokhey, S. K. Gokhale, M. A. Malandkar, and H. S. Billimoria have similarly worked out standards for the normal averages by the study of 101 healthy young women from the Bombay Presidency between the ages of 16 and 30 years.

III. The Cardio-Vascular System.

D. M. Telang in his studies of Electrocardiography described the electrocardiograms obtained from more than 50 normal individuals and showed that in the tracings of Indians no appreciable difference can be noted in the various wave amplitudes and time intervals from the accepted western standards. G. R. McRobert describes how to take care of the electrocardiograph in the Tropics.

Pal has shown that drugs which stimulate cardiac vagus or sympathetic produce vagus or acclerans substances in the heart. Further, antagonistic drugs which paralyse these nerve terminals, produce antisubstances in the heart acted upon. Drugs which act on the ganglia produce also some corresponding chemical substances in the heart. Gupta has also investigated the vagus and sympathetic tone on the cardio-vascular system and has demonstrated: (*a*) that Eppinger and Hess's conclusions about the antagonistic and exactly balancing nature of vagus and sympathetic nerves on the cardio-vascular system are not quite correct, for there may be a predominating influence on the one or the other under normal physiological conditions, (*b*) that the normal state of the system is maintained by a duplicate mechanism without a real antagonism, a central predominating vagus tone being exerted on the heart, whereas the sympathetic exerts its predominating tonic influence on the peripheral vessels, and (*c*) that a correlation between the two systems exists, for in the case of a greater vagus tone, there is a more potential sympathetic tone.

Gupta in studying the nervous regulation of cardio-vascular reactions has shown: (*a*) that the narcosis cannot exclude all the existing influences coming from the cerebrum and the higher centres to the cardio-vascular system; (*b*) that the cerebrum and higher centres normally inhibit the toxicity of presso-receptor nerves which cannot be marked completely by narcosis, (*c*) that the effect of adrenaline becomes pronounced only when these inhibitory influences from the higher centres are completely cut off, (*d*) that the effects of decerebration vary according to the plane through which the section passes, and (*e*) that probably between

thalamus and caudal part of the red nucleus there exist some centres controlling the respiratory function and there is probably a coupling of functions between circulation and respiration in this area.

Maitra thinks that cases of sudden death due to heart failure caused generally by coronary insufficiency may be averted by improving coronary circulation by inducing anoxæmia either by Pranayama, or by taking orally in the morning and in the evening one drop of 2% HCN solution, when early symptoms of pain or any other embarrassment of the heart appears.

A. Subba Rao *et al* have done important work on coronary circulation.

S. W. Hardikar has devised a recording outflow meter. It works on the principle of the siphon. The recording is done by means of the two tambour method. The outflowing fluid falls on the flattened end of the lever of one tambour and the impact is communicated by air to the writing lever of the other tambour. The advantages claimed are the ease of operation and adjustment, freedom from electrical contacts and very short working distance, which makes the instrument suitable for introduction into a closed circuit experiment on cardiac output, when the volume of drug solution under investigation is desired to be kept at a minimum.

S. A. Rahman and R. N. Abhyankar describe a method by which the recording system becomes highly sensitive to the changes of pressure in the perfusion fluid. In some of the experiments the perfusion fluid was made to enter the left systemic arch, and after having passed through the vascular system was allowed to escape through a cut at the apex of the ventricle. In the other experiments, the posterior extremities alone were perfused, the fluid entering the abdominal aorta, and after passing through the vessels of the legs escaped through the anterior abdominal vein. In both the cases the perfusion pressure tracings show a wavy character. The waves seem to be caused by the rhythmic contractions and relaxations of the blood vessels of the frog. They discuss other influences also, such as movements of the viscera in causing the waves or in modifying their character. Adrenaline tends to obliterate the waves. Ergotoxine, barium chloride, and ephedrine exaggerate the waves. Janus Green has no effect on them. The action of pituitrin is variable.

W. Burridge has investigated the reaction of heart to drugs. This included the exploration of a hitherto underscribed territory of drug action, where drugs acted at dilutions so great as one part in one billion or 10^{14}. From certain results obtained through strychnine, sparteine, atropine, etc., it becomes reasonably certain that this territory is actually corresponding to the clinical use of drugs. The traditional methods of experiment, still used in many laboratories, not only fail to reveal this territory but also may give results opposed to clinical findings. The results of some

of this work were eventually summarized in the book 'Excitability—a Cardiac Study'. In it were expounded for the first time the laws, which govern the stimulation of active beating hearts, and their modes of behaviour when so stimulated. Also a new property of rhythmic tissues was described and called '*responsiveness*'. It may be defined as the capacity of rhythmically active tissues to have their activity modified through environmental change. It differs profoundly from the property termed '*excitability*', which has been studied so much in the muscle-nerve preparation. The new knowledge of rhythmical structures thus gathered together enables its possessor to recognize, that a living organ has rhythmical action, from its reactions to its natural stimulation. The individual efforts may not be cognizable directly, but their existence can be deduced from the behaviour with the same reasonable certainty, as that with which vibration can be deduced to exist in a tuning fork, when it emits a musical note. According to Burridge the behaviour of central nervous and sensory end-organs demonstrates in them the existence of a rhythmical activity. The consequences thereof are examined in his book 'A new Physiology of Sensation'. He says that this examination demonstrates that much of what was hitherto passed as sound science in these matters is actually a series of artificial puzzles providing many differing solutions. The artificial puzzles are provided by presuming that natural stimulation is the same process as that of exciting the members of the frog's muscle-nerve preparation with electric currents, whereas it actually is the same as the stimulation of a beating heart with a drug. As a result of this fundamental change of conception such physiological phenomena, as those of the properties of colours, and of colour-blindness have now become matters of simple deduction. In his book 'A new Physiological Psychology', Burridge has made predictions of previously unknown facts, and elaborated new doctrines which are of profound interest.

Pal has shown that Lugol's iodine solution slows, but at the same time augments a normal frog's heart, that thyroxine in small doses slightly accelerates the heart, with diminished auricular complex, on prolonged action the heart becomes irregular with grouped beats; and that Lugol's iodine solution can remove completely this toxic effect and make the heart regular. Potassium iodide present in Lugol's solution is not responsible for this action.

S. A. Rahman and R. N. Abhyankar in their work on perfusion of the hearts of Indian frogs (*Rana tigrina*) found that sheeps' defibrinated and diluted blood increased both the rate and range of the heart-beat. Bayliss's solution was found to give most satisfactory results. Glucose was found to be of definite advantage in prolonging the survival period of the heart and in bringing about the regularity of beats after they become irregular, by using a solution not containing glucose. Solutions made in tap water gave better results than those made in distilled water.

B. Narayana has devised a preparation to perfuse the blood vessels of the stomach and gut of the frog and its response to drugs.

R. N. Abhyankar has elaborated a new method for investigation of the action of drugs on the vascular system of frog.

M. Basu has studied the action of Cobra venom on the heart of frogs and some tissues of the body.

N. M. Basu and P. C. Gupta have made a comparative study of the action of cobra venom and Tincture of Digitalis on frog's heart and have published a note on the effect of Cobra venom in Ca-free Ringer's Solution on the same heart.

N. M. Basu has studied the action of neo-stibosan, urea stobosan and histamine on frog's heart.

N. M. Basu has studied the effects of perfusion of frog's heart by *Brihad Kasturi Bhusan.*

N. M. Basu and P. C. Gupta have studied the action of musk in ether on frog's heart.

N. C. Bhattacharya has studied the action of strychnine on the dying heart.

S. M. Banerji has written a note on the comparative effects of cardiozol and adrenaline on blood pressure and respiration of a cat.

N. M. Basu has made observation on the relation of blood pressure to age, height, pulse and weight of some Bengalee Hindu gentlemen.

G. C. Gupta, P. Guha and P. C. Mahalanobis have estimated the systolic and diastolic blood pressure of 800 males of ages varying from 6 to 66 years. They have further extended the work, and measurements have been made on 2,100 male convicts or undertrial prisoners.

IV. Respiration.

S. L. Bhatia estimated the normal standards of Vital Capacity in Indians (Bombay), to see how far they differed from the standards given for people in Europe. 100 normal subjects, all males, were examined. The ages varied between 20 and 45. The results showed that their vital capacity figures were smaller than the accepted standards for Europeans. A great majority of them had vital capacities between 70 and 90% of the normal. While the average vital capacity of Europeans is 3500 c.c. or over, and 2500 c.c. per square meter of body surface area, for Indians the figures are about 3091 c.c. and 1960 c.c. respectively.

B. T. Krishnan and C. Vareed made a study of the Vital Capacities of South Indians, and found the average figures for 198 men to be 3·05 litres, 1·93 litres per square meter of body surface area and 18·5 c.c. per C.A. standing height. This is 75·4% of the average for American men. They also found that the average vital capacity of 23 women was 2·20 litres, which is 74·6% of the average American women.

Mason found the average for South Indian women to be 2·15 litres.

A. Subba Rao is investigating the vital capacity of lungs at Mysore.

A. S. Dale and B. Narayana made observations on the isolated lungs of the guinea pig perfused through pulmonary artery with modified Ringer or Tyrode Solution and found that excitation of the cervical vagi or injection of acetylcholine causes broncho-constriction and vasoconstriction. These effects are abolished by atropine but are unaffected by eserine. Acetylcholine caused vasodilatation in one experiment only. In one of the four experiments excitation of the stellate ganglion caused vasoconstriction. Injection of adrenaline produced vasoconstriction, and, if the tone of the bronchial muscles is already high, bronchodilatation. During rhythmic inflation bronchoconstriction diminishes the flow and bronchodilatation increases it. Eserine causes bronchoconstriction and vasoconstriction in atropinized preparations.

A. J. L. Berry, I. de Burgh Daly and B. Narayana investigated the action on perfused lungs of drugs injected into the bronchial vascular system, and found that in the entire animal under positive pressure respiration and in the isolated lungs of the dog under negative pressure ventilation, with perfusion of the pulmonary and bronchial vascular system, injections of histamine and adrenaline into the bronchial circulation cause a tidal air diminution and augmentation respectively. A constriction of the respiratory tract produced by histamine injected into the pulmonary or bronchial circulation is in general, partially or completely, released by adrenaline injected into the bronchial or pulmonary circulation.

Mathur has produced a number of papers which deal primarily with the importance of carbon dioxide in the phenomena of the circulation. He has shown the importance of this substance in the maintenance of the heart beat, and of the tone of the blood vessels. A practical point emerging from his experiments is the desirability of administering carbon dioxide in cases of heat-stroke.

Sarkar has shown that the elastic recoil value of the lung wall does not change much, but rather remains constant under different conditions of distension.

Singh and Mathur have devised for gas analysis a constant volume apparatus with a thermo-barometer attached and contained within a water-jacket. The accuracy of the apparatus is up to 0·1%.

Singh in studying the effects of intravenous injection of O_2 has found : (*a*) that a minor degree of pulmonary gas embolism accelerates the circulation, (*b*) that O_2 consumption is diminished during the period of blockage but exceeds and returns to normal when vascular compensation occurs, (*c*) that metabolism is increased by about 5% by pulmonary embolism, and (*d*) that adrenaline relieves embolic asphyxia, spasm and disordered respiration, but

this effect may be counteracted by the increase in the metabolic rate due to adrenaline.

Inderjit Singh has made observations on (*a*) the absorption of oxygen from the subcutaneous tissues, (*b*) the absorption of oxygen from peritoneal cavity and stomach, and (*c*) Intravenous injection of oxygen with animal under ordinary and increased atmospheric pressure.

N. C. Bhattacharya has studied the Reichert Gas-Regulator in Calcutta.

S. M. Banerji and D. N. Mullik have studied the glutathione content of tissues and muscular activity.

B. B. Sarkar has made observations on the importance of the bronchial musculature in the respiratory process.

S. N. Mathur finds that when an animal dies on account of heat, centres fail from above downwards in the following order: respiration, heart and vasomotor.

H. N. Banerji and S. S. Mahmud Shah have shown as the result of perfusion experiments that both the sympathetic and the parasympathetic nerves carry vasoconstrictor fibres to the lungs of the frog.

P. T. Patel has described the relation of vital capacity to intra-alveolar and intrapleural pressures in health as well as in disease, and in the therapeutic measures such as artificial pneumothorax, and in compressed air treatment of asthma.

S. N. Mathur has shown that suprarenal glands exert some tonic action on the peripheral vessels, as for sometime after their extirpation if carbon dioxide be given, it exerts a better dilator action. He has also shown that if minute quantities of adrenaline are administered to anæsthetized animals there is an appreciable increase in their oxygen consumption.

V. Digestion and Metabolism.

Digestion

D. M. Telang and S. H. Kamat made an exhaustive experimental study, both qualitative and quantitative, of the composition of the saliva and of the action of ptyalin in normal subjects. The investigations showed that ptyalin was not adaptable to diet. They also discussed the clinical importance of the *Salivary Urea Index*. M. A. Basir and T. S. Ramabhadran, working on a case of Parotid fistula, studied the physical properties and saccharogenic power of human parotid saliva. They found that it is much more active than mixed saliva, although they are both alike in physical properties. By experiments performed on the isolated frog's heart with samples of fresh human parotid saliva, and also a solution of 1 in 1000, it was concluded, that the human saliva contains a potent cardiac depressor substance, which acts directly on the myocardium.

Further work on the effect of saliva on gonads by M. A. Basir is in progress.

Mathur has shown that a diastatic enzyme is present in infant's saliva on the very first day of its birth. He finds that ptyalin is a mixture of two enzymes, dextrinase and amylase, the former being present at the time of birth, the latter making its appearance a few days later. He further states, that the diastatic enzyme is present in fæces of horse, cattle, goat, sheep, and ass, but is most abundant in that of the horse. This author has also observed, that any movement of alimentary canal and facial and masticatory muscles tended to increase the alkalinity of saliva. Fasting saliva was alkaline (pH 7·5). Psychic changes produced a change in reaction, for instance watering of mouth at the sight or smell of good food increased alkalinity, while aversion towards foods decreased it. The saliva of children was less alkaline than that of adults.

T. N. Seth has carried out investigations on the activation of pancreatic juice by enterokinase, on Gastric Urease and the relation between the metabolism and the specific dynamic action of amino-acids.

S. L. Bhatia, H. S. Patel and J. D. Dundas examined the resting gastric juice of 30 Indians living on mixed and purely vegetarian diets. They found that the total quantity of the juice varied considerably, the average being 28·473 c.c. Bile was present in 20% of all cases. Mucus was present in all. Charcoal particles (which had been given overnight), starch, blood and lactic acid were absent. In 27% of the cases HCl was absent. In those in whom it was present it varied from 2·5 c.c. N/10 NaOH (·0091% HCl) to 58 c.c. N/10 NaOH (0·217% HCl), the average being 20·23 c.c. N/10 NaOH (·07384% HCl). There was no appreciable difference between the non-vegetarians and vegetarians in regard to the amount of free HCl. Total acidity varied from 5·0 c.c. N/10 NaOH (·018% HCl) to 90·6 c.c. N/10 NaOH (0·3285% HCl), the average being 30·95% N/10 NaOH (0·113% HCl). Repeated observations on the same subject showed marked variation in regard to quantity of the juice, presence of bile, free HCl and total acidity. It was observed, that in many cases when bile was present in the juice the amount of free HCl and total acidity were relatively higher. They have made further observations on the variations in gastric acidity after a test meal. They describe a new standard test meal prepared from rice. The acid curve in the normal individual rises more or less quickly to a maximum in 1 to 1½ hours. The actual time varies however. It forms a definite peak and then falls. The height reached varies between ·16% and ·22% HCl. It has been observed, that in Indians while the amount of free HCl in the fasting juice may be very low, there is a definite rise in free and total acidity after a test meal. The emptying of the stomach also takes place comparatively rapidly, usually in 1 to 1½ hours.

Gupta and Sen on analysing the gastric contents of 100 persons (dyspeptics) have found that the behaviour of HCl curves after a meal shows four different types :—

(*a*) Sharp fall in acidity after a meal, followed by an equally sharp rise.
(*b*) Marked fall in acidity after a meal, followed by a great rise thereof, but both the fall and the rise are slower and less marked.
(*c*) A drop of acidity to nil after a meal, followed by a rise in acidity, but both the fall and the rise are much slower and much less marked and the fasting value of acidity is very low.
(*d*) No fall in acidity after a meal, but a rise which is not marked and takes on a plateau-like curve.

G. R. McRobert made observations on the hydrogen-ion concentration of the alimentary canal of albino rat.

R. K. Paul and S. Prasad have studied the effects of some products of digestion and accessory substances on the rhythmical contractions of the isolated mammalian intestines. They find that glycerine, peptone, maltose, sodium taurocholate, sodium glycocholate, indican and sodium-phenol-sulphonate are found to augment the force of contraction (some improving the force as well), whereas fatty acids, such as lactic acid, propionic acid, etc., tend to lower the tone of the intestinal muscle and also the height of contraction by diminishing the *p*H value of the intestinal contents.

Chowdhari and Kahali have shown: (*a*) that there is an optimum concentration for the absorption of glucose from the gastrointestinal tract of cat (this lies between 0·55 molar and 0·75 molar), (*b*) that the average absorption co-efficient of glucose with 0·55 molar solution injected directly into the small intestine is 0·048, and (*c*) that insulin injected simultaneously with glucose lowers the absorption co-efficient.

H. E. Magee and K. C. Sen found that calcium ions had a great influence on the rate of diffusion of sugars through the intestine. Experiment with surviving intestines of rabbits showed that in presence of calcium ion, the intestine shows some selective action against different sugars.

B. T. Krishnan has studied the function of the intestinal musculature. He describes the normal movements of the small intestine and methods for recording graphically the simultaneous action of the two muscular coats in segmenting and peristalting movements. He concludes that in the movements of the bowels there is no synchronous action of the two muscle layers, but a reciprocal action and inhibition, i.e., when the circular muscle contracts in a segment the longitudinal muscle relaxes and vice versa. The pendulum movements are considered to be only longitudinal muscle phenomena. In peristalsis, there is a wave of

longitudinal muscle contraction with the circular muscle relaxed, ahead of a wave of circular muscle contraction with the longitudinal muscle relaxed. The 'law' of Bayliss and Starling is applicable only to the action of the muscle layer. He has examined and analyzed the rates, amplitudes and rhythmical contractions observed in excised segments from different regions of the bowels, and those observed in the intact animal (cat), and has also discussed if the intestinal movements are neurogenic or myogenic. He adduces experimental evidence to show that the rhythmic contractions become slow and irregular, or cease altogether, whenever a neurotropic poison is injected into an animal or painted on the intact animal, or added to a bath containing excised segments of the bowel. He concludes that although intestinal muscle may show automatic rhythm, it is to large extent dependent upon enteric nerve cells and fibres for its normal rhythmic activity.

B. T. Krishnan has also shown that all parts of the small intestine are equally well stimulated by histamine and acetylcholine, and that atropine inhibited the stimulating effect in both the intact and isolated bowel.

Metabolism

S. L. Bhatia and G. Coelho have shown that the average fasting blood sugar in Indians is slightly higher than the normal. It is a little higher in vegetarians than non-vegetarians. They have obtained sugar tolerance curves from quite a large number of normal individuals after administration of 50 grms. of glucose. The curves show the same general features as those obtained in European countries. The non-vegetarians show a better tolerance for carbohydrates than vegetarians. The renal threshold for sugar appears to be in the neighbourhood of 0·17%. They are of opinion that excessive consumption of carbohydrate food interferes with the glycogenic function of the liver, throws a strain on the internal secretion of the Islets of Langerhans, and thus leads to a lowered tolerance for sugar. This accounts for the wide prevalence of glycosuria in the country.

Bagchi and Rudra have shown that in India just as in Europe and America the sugar content of normal urine is always lower than that of normal blood, and that the vegetarians have a higher sugar content both in urine and blood than non-vegetarians.

McCay and his co-workers, who made observations on the blood sugar and sugar in urine in Bengal, had also found, that they had high fasting sugar levels, and they attributed this to the high carbohydrate content of the diet. Brahmachari and Sen obtained similar results.

S. L. Bhatia has stressed the preventive aspect of Diabetes Mellitus. The important aetiological factors in this disease, according to him, are three :—

(*a*) *Overeating*, specially excess of carbohydrates in the diet, combined with lack of exercise.

(b) Obesity.
(c) Mental Strain.

He calls them the '*Diabetic Triad*'. They are of special importance in India. The problem of prophylaxis is one of *personal hygiene*. 'We have to advocate moderation in eating, a properly balanced diet not containing excess of carbohydrate, avoidance of obesity, moderate amount of physical exercise taken regularly, and a calm and placid temperament avoiding all worry and anxiety.'

Bose and De have examined 100 diabetes and a large number of healthy Indians, and find that the average cholesterol content of plasma in normal healthy Indians is 140 mgm. (variation from 120 mg. to 160 mg.) and is independent of the race factor, that there is no relationship in diabetes between cholesterol content of blood and hyperglycæmia; and further that hypercholesteræmia is always associated with various complications including arteriosclerosis. They state that hypercholesteræmia in diabetes is a much more satisfactory index of the severity of the disease, than any one of the other factors, including hyperglycæmia.

S. C. Sen and P. N. Chowdhury have made studies on the increase of blood calcium after intravenous administration of glucose.

Important investigations have been carried out in regard to the Basal Metabolic Rate in Indians in most parts of India. Mukerji and Gupta have investigated it in Bengalis, Mason and Benedict in South Indian women, Banerji in the prisoners of the Lucknow District Jail, S. S. Sokhey, M. A. Malandkar, and J. D. Dundas in Bombay, B. T. Krishnan and C. Vareed in Madras and S. A. Rahman in Hyderabad (Deccan). In all cases the Basal Metabolism is about 10 to 15% below the accepted standards for Europeans and Americans. There are obviously racial and climatic factors which are responsible for this.

The findings of S. A. Rahman are interesting, namely :—

1. That no difference exists in pulse and respiration rates as compared with the western standards.
2. That the subjects have about 1 cm. shorter stem height and correspondingly longer legs compared to westerners.
3. That a pelidisi of about 92 is probably the index of normal nutrition amongst Indians, the average pelidisi being 92–4.
4. That the blood pressure is considerably lower than the Western standards.
5. That the basal metabolism is 6·8% below Harris Benedict and 8·7% below Aub-Du-Bois standard; and
6. That vegetarians show 2% lower basal metabolic rate.

He has also studied the influence of humidity on Basal Metabolism.

S. L. Bhatia and his co-workers have been doing further work on this subject in Bombay, while A. Subba Rao is doing the same in Mysore.

J. P. Bose and U. N. De have also determined the B.M.R. of Indians in health and disease and discuss the clinical significance of the results obtained.

N. C. Bhattacharya and S. C. Sen have made observations on the Kata-thermometer in Bengal.

VI. Dietetics and Nutrition, including Vitamins.

(a) *Dietetics and Nutrition.*

S. L. Bhatia has reviewed the problem of Nutrition in India in the light of the recent publications of the League of Nations on Nutrition. He draws attention to the prevalence of malnutrition in this country owing to the lack of both 'protective' and 'non-protective' foods. Lack of 'good' protein, deficiency of caloric requirements, incomplete and sub-optimal value of the dietary, deficiency of certain essential vitamins and mineral salts are the important factors. The enormous amount of ill-health in pregnant and nursing mothers, due to improper diet, as evidenced by Osteomalacia and Anæmia is a matter of grave concern. Proper nutrition in infancy and early childhood is another important matter. Suitable dietetics in the young are a *preventive* aspect of our work. He has amended the League of Nations' Table giving the Nutritive value of Foods. He emphasizes three problems concerning nutrition which await solution :—

1. The influence of tropical climate on food requirements.
2. The proper intervals at which food should be taken. This has an important practical bearing on the work efficiency of the individual.
3. *Vegetarianism.* In view of the large proportion of our countrymen who live on a purely vegetarian diet, systematic investigations are necessary to appraise the precise influence of vegetarianism on body nutrition, and the direction in which improvement should be made.

Aykroyd and Rajagopal have investigated the state of nutrition of over 1,900 boys (aged 6 to 15 years) and find that Indian children of a given height weigh very much less than British and American children of the same height; that 14% boys show food deficiency diseases, 6·4% phrynoderma (not due to Vitamin A deficiency), 9·6% Angular stomatitis and 3·8% Bitol's spots; that on investigating the A.C.H. index of 1,145 boys, it is found that the index needs adjustments to make it suitable for routine work in India; and that climate alone has no advantage as regards physique and state of nutrition.

D. M. Telang wrote a comprehensive review and discussion of the human diet from prehistoric to the present times.

S. P. Niyogi, V. N. Patwardhan and R. G. Chitre have studied the problem of 'balanced diets', by analytic methods and by observing their effects on the growth and reproduction of albino rats. The Bombay Presidency Baby and Health Week Association have formulated 'balanced diets' at a maximum monthly cost of Rs.6 per adult. These have been carefully analyzed as to their adequacy. The work is in progress. Attempts are being made to evolve a physiologically ideal diet. S. P. Niyogi, N. Narayan and B. G. Desai have studied the nutritive value of Indian vegetable foodstuffs. They have isolated and analyzed the globulins of two Indian pulses, *Phaseolus radiatus* and *Phaseolus mungo.* The biological values and digestibilities of the proteins of *Phaseolus radiatus*, *Phaseolus mungo*, *Cajanus indiens* and *Pisum avense* have been determined by Mitchell's method at a 10% level of intake. From these values the net available protein contents of the pulses have been calculated. They find that only about 50% of the total proteins of the ten of the commonest Indian pulses, which they have analyzed, are available for the processes of growth and repair in the animal body. They have studied also the nutritive value of Ragi (*Eleusine Coracana*), and find that the ragi proteins seem to be superior to those of rice and oats in their biological values. They have also conducted experiments to prepare ragi malt.

Mathur has investigated the digestibility of various types of rice and the best methods of cooking. He has shown, that an enzyme capable of acting on rice appears in the saliva of infants at a much earlier age than was previously believed. Narendra Singh examined the diets of various classes of inhabitants of United Provinces and noted to what extent they might be deemed to be adequate or deficient.

Wilson and Mukherjee have shown that there is no increase in intestinal putrefaction on a rice diet as compared to wheat diet, that there is no selective absorption of valuable amino-acids containing sulphur, that the urinary out-put is greater on a rice diet than on a wheat diet (this being probably due to a greater salt intake on a rice diet); and that the increased turn-over of water by the alimentary canal is probably unfavourable to the action of intestinal organisms even though there is a large residue of fœcal nitrogen available as a medium of micro-organisms.

Sahu discusses the importance of calcium in medicine, dealing with its absorption excretion and functions. In view of its importance he has determined the calcium-content of some of the commoner dietaries of India.

Vitamins.

Some important investigations on vitamins have been carried out in India.

(b) *Vitamin A.*

The distribution of carotine in common foodstuffs, its stability under different conditions of storage and cooking and its metabolism have been the subject of numerous studies in different laboratories.

N. K. De has published the carotene content of some eighty foodstuffs by a modified spectrographic method devised by himself. Many leafy vegetables have been found to be rich source of carotene, which however, deteriorate rapidly on storage. Root vegetable, with the exception of carrots, yams, etc. are generally poor in carotene. The carotene content of many fruits was found to increase during ripening. Similar increase was also found in many vegetable foods, such as roots and pulses, during storage, indicating that the synthesis of carotene continues long after harvesting or plucking.

De also investigated the stability of the pigment in a number of vegetable foodstuffs under different conditions of storage cooking and sprouting, etc. He observed that there is no appreciable loss of pigment (carotene) if vegetables are kept sprinkled with water wrapped in pieces of damp cloth. In such vegetables there is not much loss of carotene during boiling. Dals and legumes lose much of carotene during cooking.

Ahmed, Mullick and Mozumdar investigated the carotene content of common Bengali food using colorimetric method. Their results are more or less similar to De's. Some of the local 'Ságs' were found to be rich sources of this factor.

Ahmed studied the fate of carotene after absorption from the intestinal tract, and observed that absorption of carotine was influenced by the composition of diet. Rats fed on fat free diet were found to excrete 90 per cent. of carotene, whereas with diet containing 10 per cent. of fat the absorption of carotene was complete. Evidence was obtained of the presence of a substance resembling Vitamin A in the coecum of the rats fed on diet deficient in Vitamin A but supplemented with carotene.

Investigating the metabolism of carotene in different animals *Ahmed and Malik* find that the amounts synthesized by the rat, chicken, rabbit, pigeon, and cat are in the proportion of 100 : 24 : 16 : 1·2 : 0 respectively. The difference in the amount of Vitamin A, synthesized by the different animals are not due to difference in their normal vitamin requirements, but to differences in their capacity to utilize carotene for Vitamin A formation.

Ahmed suggests that in the conversion of carotene to Vitamin A in the organism, the reticulo-endothelial system plays an important part. Colloidal carotene injected intravenously into the dog was found to be stored in the spleen, which is ordinarily deficient in Vitamin A. He suggests that in the higher animals like the cat and the dog, in which the spleen is more highly developed and contains

in its meshes a large proportion of the reticulo-endothelial cells as compared to the liver, Vitamin A may first appear there.

Ahmed and co-workers injected carotene intravenously in four different species of animals. The rats which can readily assimilate carotene and conserve large stores of Vitamin A in the liver, when fed orally with carotene in oil medium, failed to do so on intravenous injection of the pigment. Dogs behave likewise, but rabbit liver was found to contain Vitamin A which could be proved to have been derived from the injected carotene.

Wilson, Ahmed and Mozumdar observed that the composition of diet and the form in which carotene is fed affect the absorption of carotene from intestinal tract of animals. There is much better absorption when the carotene is fed mixed with oil or in the form of natural foodstuff. The feeding of 5% bile or 15% meat did not appreciably increase the absorption (as shown from the amount of carotene from the fæces). But the amount of Vitamin A stored in the liver indicated that there was better assimilation from both these diets.

Similar results were obtained by Wilson, Dasgupta and Ahmed in their experiments on the absorption of carotene in human subjects. 78 to 89% of carotene ingested in the form of carrots and spinach was absorbed on an ordinary Bengali diet. The absorption fell to 52%, when fat was cut off from the diet. With a Vitamin A concentrate, there was complete absorption with or without fat in the diet. The requirement of the organism for carotene would, therefore, appear to be somewhat greater than that for Vitamin A.

Guha and Chakravarty investigated the Vitamin A content of Indian mango. As regards Vitamin A, all varieties appear to be potent sources of this factor. The Vitamin A content of mango was found to vary with different varieties.

Ghosh and co-workers estimated the Vitamin A content of Indian fish liver oils—the Carr-Price value of liver oils from Chital (*Notopterus chitala*), Silong (*Silumpia silompia*), Kalibaus (*Labeo calbasu*), Dhain and Âr are 206, 75, 19, 175 and 93 respectively.

Chakravarty and co-workers observed the Carr-Price values of the liver oils from *Labeo rohita, Cirrhina mrigala, Catla catla Hilsa ilisha* and Lates *calcarifer* 227, 174, 109, 59, 284 respectively.

Nag and Banerjee find that the Vitamin A potency of Hilsa liver oil is equal to that of *halibut* liver oil.

Datta and Banerjee determined, both by colorimetric and the biological methods of assay, the Vitamin A content of the body oils of some of the freshwater fish of Bengal. The values obtained by the two methods of assay agree fairly closely. The body oil of *ruhee* and *mirgal* are found to be half as rich in Vitamin A as de Jongh's cod-liver oil.

Ahmed finds halibut liver oil to be 24 times as rich in Vitamin A as an average sample of cod-liver oil. Colorimetric tests gave

values for the halibut liver oil, which were in close agreement with that obtained by biological tests.

Ghosh and Guha obtained fairly close agreement in the Vitamin A values of Indian fish liver oils obtained by the biological and inctometric method.

De reports that the human, cow, goat, and buffalo milk contain roughly the same quantity of Vitamin A, about 50–100 per 100 c.c. of milk, an amount equivalent to that contained in 0·15 to 0·2 gram of cod-liver oil.

Banerjee and Sunawalla made a Vitamin A assay of ghee; the values for all pure samples were roughly alike, the variation in yellow colour did not necessarily follow differences in Vitamin A content.

Basu claims to have produced Vitamin A by the ultra-violet irradiation (light of wave length 2750–3000 Å) of a sterol isolated from egg yolk. The irradiated product gave all the characteristic chemical and physical properties of the vitamin. He has also succeeded in isolating crystalline Vitamin D from the oil of *Notopterus chitala*, a common fish in Bengal. The properties of crystals agree fairly with those of Calciferol.

M. V. K. Rao has made an extensive study of the histological changes in the sensory nerve of the eye and its relation to xerophthalmia in Vitamin A deficient rats, rabbits and fowls. He did not find any evidence that nerve degeneration was the immediate cause of the epithelial changes occurring in the eye. There was no parallelism between the intensity of the degenerative changes in the sensory nerve and the intensity of the eye lesions. When xerophthalmia healed up in animals by the addition of carotene to their diet, recovery of the lesions in the corresponding sensory nerve did not take place.

Aykroyd and Krishnan observed high incidence of Bitot spots (yellow foamy patches on the conjunctiva), and other positive eye changes associated with Vitamin A deficiency among children in labour camps in Southern India. The diet of these children was entirely devoid of Vitamin A, and contained on an average 0·683 mg. of carotene per day. Aykroyd and Krishnan consider the optimum requirement for children to be in the neighbourhood of 1·8–3 mg. carotene per day.

E. Surie has made observation on biological assay of Vitamin A in the diet of Indians.

(c) *Vitamin B.*

Guha and Chakravarty reported the Photochemical Synthesis of Vitamin B, by the ultra-violet irradiation of adenine sulphate and demonstrated the identity of the irradiated product with Vitamin B, by means of biological tests carried out on rats.

Schultz and Faquer report that true healing of polyneuritis could not be observed on treatment with irradiated or non-irradiated

adenine sulphate and conclude that the apparent finding of Guha and Chakravarty are due to 'use of unreliable method of assay'.

Later Guha and Chakravarty report that they find the irradiated product has proved unable to cure 'poly-neuritis' in pigeons in 5 mgr. doses but the same daily dose supported growth in 36 young rats which had ceased to grow on a diet composed of starch, caseinogen, salt mixture supplemented by cod-liver oil and an aqueous extract of ox-kidney which provided Vitamin B_2, and a small quantity of Vitamin B_1. The above result indicate the formation of a growth promoting substance on irradiation of adenine.

Guha and Chakravarty extended their investigation on Vitamin B_2 in the extract of livers of different species of animals and also in extract of ox-spleen, ox-muscle and ox-kidney. Ox and buffalo kidney extracts were found to contain 67 and 87 units of Vitamin B_2 per 100 grms. of tissue. (A unit of Vitamin B_2 is the amount which when administered daily to young Vitamin B_2 deficient rats, would produce a weekly gain in weight of approximately 10 gram for a period of 2 or 3 weeks.) Fowl liver is also a good source of Vitamin B_2. The extraction of Vitamin B_2 from liver is stated to be optimum at *p*H 5.

Guha and Biswas obtained a new flavine from ox-kidney capable of producing good growth in young Vitamin B_2 deficient rats in daily dose of 0·2 to 0·3 milligram. They suggest that the flavine belongs to the byochrome group of pigment and have termed it 'Renoflavine'.

McCarrison and Sankaran found that the growth in *vitro* of intestinal epithelium of the embryo chick to be greatly impaired by a deficiency of Vitamin B in the plasma, wherein the intestinal tissue is cultured. The impairment is dependent to some extent also on other changes in the plasma brought about by subsistence of fowls, from which plasma is obtained, on the rice diet whose major fault is one of deficiency of Vitamin B.

Guha and Biswas continuing their work on Renoflavine find an improved growth response on rats, if small amount of the flavine-free kidney extract, previously autoclaved, were given as supplementary dose. These results led the authors to conclude that the Vitamin B_2 complex consists of four factors.

Guha recognizes four factors in Vitamin B_2, a flavine, a heat and alkali stable substance, 'an antidermatitis' factor, and an 'anticataract' factor. He pleads that the term Vitamin B_2 should be retained to describe the entire complex, which when added as a supplement to a Vitamin B_2 deficient diet promotes good growth in rats and prevents dermatitis.

Sankaran and Krishnan have confirmed observation of *Harris* and his colleagues that a drop in the rate of the heart occurs in Vitamin B deficient rats and pigeons, which rapidly return to normal when food rich in Vitamin B is given. This observation has been made use of in the assay of Vitamin B, in foods.

From Electrophoresis experiment Narasimhamurty concluded that the iso-electric point of Vitamin B_1 lies between pH 9 and pH 10.

Ghosh and Dutt have employed a modified form of Spruyt's colorimetric method for the estimation of Vitamin B in foodstuffs. The method was utilized for the Vitamin B assay of several samples of Indian rice collected and prepared under standard conditions. The Vitamin B content was found to diminish with the degree of hulling and polishing, subsequent washing decreases it further. The effect of polishing was found to be more pronounced in raw than in parboiled rice.

Rudra and Bagchi find that ordinary mill-polished rice available in bazaar contains sufficiency of Vitamin B for normal maintenance and health. When the rice is repeatedly washed and boiled and rice water thrown away, the vitamin is lost. Under the conditions of cooking in Indian homes, Vitamin B_2 present in rice is not lost.

Ghosh and Guha have estimated the protein, calcium, iron, phosphorus and Vitamin B_1 and B_2 of a few foodstuffs in common use in Bengal. Some vegetables were found to be good sources of Vitamin B_1 and B_2. These vegetables cannot, however, compare with cereals in their potency for Vitamin B_1 or with liver in their content of Vitamin B_2.

Ahmed, Ray and Guha reported the Vitamin B_1 assay of forty different foodstuffs comprising common vegetables and cereals. The vegetables were found to be relatively poor in B, the value in international units being 10–40 per 100 g. of food materials. The cereals and legumes are rich in this factor, the mean value being about 150 units. The value for wheat is 100–110, while that of polished rice is only 26. The Vitamin B_1 value of parboiled rice is somewhat better.

Das and Guha investigated the comparative value of cow, goat, buffalo, and human milks with respect to their Vitamin B_1 and B_2. They found that human milk to be least potent among the different varieties investigated. On both Vitamin B_1 and B_2 deficient diet a supplement of 10 c.c. of human milk (19 total milk solid) failed to support growth of young rats. The authors consider that the milk of Bengali women may probably contain sub-optimal amount of B vitamins.

Rudra and Bagchi found that rice water obtained from mill-polished rice contains Vitamin B and that a daily dose of rice water from 20 grams of polished rice is sufficient to cure polyneutritis in pigeons.

Aykroyd and Krishnan found that the incidence of angular stomatitis is very common in children in South India. Indeed in two hostels near Coonoor, the authors observed that in the boys' hostel 50% of the boys and in the girls' hostel 71% of the girls were suffering from angular stomatitis. The diet of the hostels

was very poor and consisted largely of milled parboiled rice. The supplement of 0·5 oz. of cod-liver oil daily for three weeks had no effect in curing the conditions. The addition of 1 g. of dried brewers' yeast as such or autoclaved for 5 hours at 120°C, completely cured the erosions at the angles of the mouth and soreness of the tongue in 4-5 weeks. They were also cured in 3-4 weeks by feeding with 1·5 oz. of dried skim milk powder free from Vitamin A. The authors concluded that one or more of the factors of Vitamin B_2 group were concerned in this condition.

D. D. Chatterje found that rats and pigeons deprived of Vitamin B, would die of starvation in the midst of an abundance of food. He, therefore, suggested that this vitamin had an important influence on appetite. He had to leave undetermined, however, to what extent this loss of appetite was due to lesions of the doudenum, or nasal mucous membrane or to other factors. His own untimely death is to be deeply deplored.

(*d*) *Vitamin C.*

Prof. Szent-Gyorgyi's discovery that hexuronic acid (now termed 'ascorbic acid') is identical with Vitamin C provoked considerable work in the direction.

Harris and Ray have confirmed by chemical, biological and spectrographic examination the specificity of hexuronic acid (ascorbic acid) as the antiscorbutic factor.

Birch, Harris and Roy have developed a rapid micro-method for estimating the hexuronic acid content of foods. The method consists in the preliminary grinding of the material with sand and tri-chlor-acetic acid, followed by titration of the acid extract against a measured volume of the oxidation-reduction indicator, 2 : 6-dichlorophenol-indophenol. An amount of Vitamin C represented by 0·03 c.c. of orange juice suffices for an accurate assay.

Harris and Ray investigated the loss of potency of guinea-pig supra-renals in scurvy. The supra-renals of normal guinea-pigs possess powerful antiscorbutic activity and appreciable amount of ascorbic acid, but the activity disappears along with the hexuronic (ascorbic) acid content when Vitamin C is withheld from the diet. The behaviour of guinea-pigs is contrasted with that of dogs and rats,—animals, which can synthesize Vitamin C when none is provided in the diet.

The medulla as well as the cortex of the adrenal is found to be rich in Vitamin C. Weight for weight, the ox-cortex is about thrice and the medulla about twice as potent as orange juice. Discussing the significance of Vitamin C in the adrenals, Harris and Roy observe that it cannot be regarded as a reserve store of the body. They suggest that the need of Vitamin C is probably for protecting the functional activity of the organs. Although rat's adrenals are thrice as rich as the ox's in Vitamin C, yet their

experimental evidence is definitely against the theory that synthesis of Vitamin C in animals like dog and cat occurs in the adrenals.

Harris and Ray find that Vitamin C is normally excreted in the urine. The amount excreted in normal individuals is constant, being about 30 to 33 milligrams of ascorbic acid per day. Large intake of this vitamin causes in the normal subject the urinary Vitamin C to increase rapidly to a maximum in about three hours, followed by a drop to the 'normal' rate within a day, even if a Vitamin C free diet is given in the interval.

Harris and Ray made an exceedingly useful contribution to the diagnosis of Vitamin C subnutrition by examining the Vitamin C content of urine. The amount of Vitamin C excreted in the normal individual being constant, 30–33 milligram of ascorbic acid per day, persons suffering from manifest scurvy or subsisting on diets deficient in Vitamin C excrete little Vitamin C in urine, and the administration of a single large dose of this vitamin does not cause a corresponding rise in urinary secretion, such as is observed in normal subjects.

Ahmed discovered a considerable increase in reducing capacity of urine after high protein diet with an increased ingestion of Vitamin C.

Chakravarty and Roy also recorded high ascorbic acid value of urine on high meat as well as high fat diets.

Guha and Ghosh made similar observations on rats.

Chopra and Roy observed that the evidence as to the identity of the indophenol reducing substance in urine with ascorbic acid was not conclusive as the biological tests were not satisfactory.

Heinemann finds that if the titration is carried out after precipitation with mercuric acetate, the urinary excretion of ascorbic acid is not influenced by the proportion of protein in the diet. The amino acid 'cystine' of the protein food is the source of thiosulphate in the urine.

Guha and Ghosh found that the isolated liver, spleen and kidney tissue of the rat incubated at 37° in a medium of Ringer-Locke solution and phosphate buffer at *p*H 7·4 are able to convert mannose but not glucose, fructose, galactose, xylose and arabinose into ascorbic acid. Amounts of the order of 0·30 to 0·35 milligram of ascorbic acid are found to be formed from mannose per gramme of each of the tissues after three hours' incubation. The mannose dehydrogenase system responsible for the dehydrogenation of mannose into ascorbic acid, has been extracted from acetone-dried tissue with water. The cell-free extract of liver is able to produce 0·07 milligram of ascorbic acid from mannose per gramme of tissue under above conditions. The corresponding tissues of guinea-pigs are found unable to convert mannose to ascorbic acid.

Guha and Ghosh continued their work on the synthesis of ascorbic acid (Vitamin C) by tissue *in vitro*. Liver tissues of rats, rabbits and pigeons were able to synthesize ascorbic acid from

mannose *in vitro* while those of guinea-pigs and monkeys were unable to do so. This power of synthesis is not common to all animals independent of an external supply of ascorbic acid from their bodily needs, as the liver of the ox, cat and fowl, for example, cannot convert mannose into Vitamin C *in vitro*. The same authors succeeded in extracting the mannose—dehydrogenase system from the spleen, kidney and liver tissue of rats. They extracted a similar enzyme system from germinating mung (*Phaseolus mungo*) which converts mannose into ascorbic acid at pH 5·8 : but not at pH 7·8.

These *in vitro* experiments with rats have been confirmed by Guha and Ghosh by experiments *in vivo.*

Euler, Gartz and Malmberg could not confirm their experiment on the biosynthesis of ascorbic acid from mannose by liver tissue of rats. If the incubation of liver tissue is done in an atmosphere of nitrogen as done by Euler and colleagues, no synthesis of ascorbic acid takes place. But aerobically, and at the end of three hours' incubation at 37°C, 10–35% increase in ascorbic acid is observed in liver tissue of rat suspended in a mannose solution.

Wats and White made a systematic assay of Vitamin C in fruits. The fruits examined ranged themselves into the following descending order as regards their Vitamin C content :—Pumelos (*Citrus decumana*), pineapples (*Bromelia ananas*), orange, lemon and bananas (*Musa paradiasca*). Sweet lime pomegranates (*Pumica granatum*) and pears (*Pyrus communis*) were found to be poor sources of Vitamin C.

Wats and Eyles made an assay of several germinated pulses, tomatoes, mangoes, and bananas. Of the various pulses investigated, Mung (*Phaseolus mungo*) was found to be the best as regards its Vitamin C content, and the ease with which it germinated. Tomatoes were found to be good source of Vitamin C, the mangoe less so, requiring 10 gramme to protect guinea-pigs against scurvy.

Guha and Ghosh observed a sixfold increase in the reducing power of *Phaseolus mungo* during germination, on the basis of dry weight. The increased reducing power has been attributed to the synthesis of Vitamin C during germination.

Several investigators in different laboratories have employed the chemical method for the estimation of Vitamin C content of common Indian foodstuffs.

S. N. Ray has shown, that the amount of Vitamin C required by guinea-pigs for complete protection is greater in the cases of animals fed on desiccated thyroid.

K. Chakravarty and B. C. Guha have worked out a special method for the estimation of ascorbic acid in urine.

P. N. Sen Gupta and B. C. Guha have estimated the total (combined and free) Vitamin C in several vegetables and foodstuffs and have developed a process for the purpose.

Ahmed estimated the ascorbic acid content of about 65 samples of common Indian fruits, vegetables and pulses, by chemical methods. He has tried as far as possible to obviate errors likely to arise by adjustment of concentration of trichlor-acetic acid during the final titration. He finds that the concentration should not exceed 5% and the titration should be finished in one or two minutes.

Ranganathan estimated the ascorbic acid content of 100 common Indian foodstuffs. It was found to vary with the locality, season of the year, rainfall, manuring and the different stages of growth of vegetables. The author followed the hot acetic acid extraction of vegetable material, which is more satisfactory, giving a sharp end point than the trichloro-acetic acid extraction method.

Rudra finds that Vitamin C is more concentrated in the skin of fruits and vegetables than in the inner edible portions. In root vegetables Vitamin C is in the greatest concentration in the leaves. In animal foods the descending order of concentration was as below: liver, kidney, bone-marrow, milk, heart, muscle.

Chakravarty, Roy and Guha studied the effect of feeding orange juice to lactating women and found that after ingestion of 109 mg. ascorbic acid as orange juice the concentration in the morning milk increased 1·5 time the normal concentration.

N. M. Basu and P. Das have investigated the Vitamin C content of a number of fruits and some articles of food, which are eaten raw. They find, that the juice of 'Tulsi' leaves, green 'Lanka', and small 'Mula' contain a fairly large amount of Vitamin C.

J. C. Pal and B. C. Guha have studied the ascorbigen content of a number of vegetable and animal foods. They find that leafy vegetables contain considerable quantities of it, while acid ones contain practically nil.

Sankaran and Krishnan in investigating the effect of Vitamin B_1 and C deficiency on the heart-rate, have noticed that (i) pigeons and rats fed on a Vitamin B_1 deficient diet show a drop in the heart-rate (Brady-cardia), and (ii) guinea-pigs fed on a Vitamin C deficient diet show a rise in the heart-rate (Tachycardia).

(e) *Diet and Stones.*

Newcomb and Ranganathan have classified the stones on the basis of the amount of the main constituents as urate or oxalate stones. Urate stones were most common (53%), oxalate stones coming next (17%) and phosphates (12%).

The stones from the rats were found by the authors to be mainly magnesium ammonium phosphate stones. Uric acid was either very little or none in the stones from rats.

Ranganathan observed that diet had an influence on the composition of stones, produced artificially in rats.
duced on a diet containing extra lime consisted
and carbonate, with very little phosphates,

The moisture content which varied between 2·10 to 49·3% roughly indicates whether calcium existed as carbonate, hydroxide or a mixture of both.

An important series of papers contributing towards the knowledge regarding formation of stone in the bladder has been communicated by McCarrison. Diets deficient in Vitamins A and C containing an excess of calcium favoured stone formation but excess of lime has no influence if good food is given. When cereals formed the bulk of the diet, the capacity of various cereals to favour formation of stone in rats is in the following order :—wheat, oats, rice, ragi, and cumbu (bajre). A liberal supply of butter in the diet comprising of oatmeal, cornflour, sodium chloride and calcium phosphate prevented the formation of urinary calculi in rats. The effect of diet on stone formation has been the subject of a very interesting series of investigations by McCarrison and his co-workers.

McCarrison had shown that well fed rats kept under hygienic conditions are protected from stone formation. Rats fed on basal diet consisting of white bread and yeast developed stones in 14·6% of cases. Addition of lime, 3 grains per day, increased the incidence. Radiostoleum containing both Vitamins A and D afforded protection, which was more marked when quantity of lime was further reduced to 1·5 grains per day.

Ranganathan has shown that greater protection against stone formation is afforded if, in addition to Vitamins A and D the diet contains a proper proportion of phosphates.

Extensive investigations by McCarrison and Ranganathan have shown that the imbalance between several chemical constituents of food may be as much responsible for the formation of stone as a deficiency of certain accessory food factors.

Analyses of the nuclei of human urinary calculi showed that uric acid and urates formed the chief constituents.

Megaw investigated the relationship between the incidence of stone in the bladder in three chief communities of the Punjab and their diet. He concluded that stone formation is likely to be less among people who eat a well-balanced nutritious diet containing large proportion of milk than among those whose diets are unsatisfactory in these respects. These epidemiological investigations are confirmatory of the conclusions reached, on experimental grounds by McCarrison.

Ranganathan attempted the production of uric acid calculi in albino rats, but his observations indicate that the experimental production of uric acid calculi in albino rats is not possible.

Wilson and Coombes conducting an osteomalacia inquiry in Northern India and Kashmir found that rickets in its various forms tends to occur in any race or caste whenever there is extreme deficiency of sunlight or diet or more frequently where there is relative deficiency in both factors. Sex incidence shows that in late rickets and osteomalacia, the chief strain falls on girls and

women during adolescence and maturity. The best treatment is administration of Vitamin D with the daily use of milk, fresh fruits, greens and exposure to sunlight.

Wilson and Mukerjee investigated some of the possible factors in the causation of vesical calculus in India, apart from such causes as vitamin deficiency, infection and cereals as staple article of diet. They observed a reduced urine volume on an 'atta' diet as compared with rice, possibly due to a diminished salt intake on the former diet, accentuated by a diuretic principal present in the latter.

Ranganathan has also reported an increased urine volume on the rice diet in rats as compared to that voided on 'atta', 'cambu' or cholam diets.

(*f*) *Diet and Anæmia.*

Wills and Talpade have concluded as a result of extensive studies in pernicious anæmia of pregnancy, that deficiency of Vitamins A and C may be the causative factors. Proportion of fat and Vitamin B determine the incidence of the disease.

Wills and Mehta could produce severe anæmia in rats on diets deficient in Vitamins A and C. It was more frequent in females. Studies showed the presence of *Bartonella muris* in the red cells of anæmic rats. Finally they found that only those rats which were pregnant and which were fed with so-called Bombay Hindu diet and innoculated with *Bartonella* infected blood developed anæmia.

McCarrison and Mula Singh found that rats that have recovered from *Bartonella muris* anæmia following splenectomy, may develop the disease again at a later date and succumb to it, although during the intervening period they have been well fed and hygienically caged.

Lucy Wills and Billimoria produced a macrocytic anæmia in monkeys by feeding them on diets deficient in Vitamin B. The anæmia so produced was curable by addition of 'marmite' to the diet but not by the addition of Vitamins A or C.

Mudaliar and Sarasimha Rao find that neither Vitamin B administered as marmite nor Vitamins A and C produced any therapeutic response in their cases of pernicious anæmia. They find that the malady is deficiency disease, not of vitamins but of anti-anæmic factor.

Lucy Wills indicates the possible causes of failure of response to the treatment by marmite in tropical macrocytic anæmia, including pernicious anæmia in pregnancy.

Extending her investigations on anæmia Wills arrived at the conclusion that tropical macrocytic anæmia is a simple condition of dietary deficiency. The curative action of marmite in this condition has been confirmed in the present studies.

In studying the nature of the curative principle of marmite, Wills found that the hæmopoietic fraction is water-soluble and

heat-stable in acid medium. It is not precipitated or inactivated by 80% alcohol. The hæmopoietic fraction does not belong to the recognized fraction of Vitamin B complex.

Gupta finds that treatment with liver extract by intramuscular injections and iron by mouth has proved beneficial in some of severe cases of pernicious anæmia of pregnancy.

Balfour and Wills have given an account of the clinical aspect, blood picture and response to treatment of two main types of anæmia among pregnant women in India. The first is macrocytic anæmia responding to the treatment of marmite or usual liver preparations. The second type is an iron deficiency anæmia of the microcytic type associated with severe form of hookworm infection. This responds to massive oral doses of iron.

Chakravarty observed that the milk of Bengali Mohammadan women was definitely poor in Vitamin C (0·03 mg. ascorbic acid per c.c.) as compared to the milk of other communities in Bengal, Hindu, Marwari or Anglo-Indian (0·05 mg. per c.c.). The difference may be ascribed to lower nutritional level rather than to any racial factor.

On boiling or pasteurizing, cow's milk was found to lose 50% or more of its Vitamin content. Chakravarty estimates the normal value to be 0·02 mg. per c.c. which is reduced to 0·01 mg. after pasteurizing and to 0·007 mg. after boiling for 5 minutes.

S. L. Bhatia has reviewed the problem of Vitamins with special reference to nutrition in India. N. C. Bhattacharya has studied the Vitamin factor in Bengali diet.

S. C. Devadatta and his assistants have estimated the various forms of phosphorous compounds in milk—ortho and pyrophosphates, phosphoric esters and creatine phosphuric acid. The amount of reducing sugars, calcium and magnesium are determined with a view to establish the relation, if any, between the ortho- and pyrophosphates and calcium and magnesium in milk. They are also estimating Vitamin C in Indian vegetables and grain. Analysis of fruit, *Achrus sapota*, commonly known as Chikku, has been undertaken. It is found to contain calcium, iron, phosphorous and carbonate in different quantities in the skin and in the pulp.

Mathur thinks that tomatoes or similar other fruit should be taken by school children instead of sprouted gram for the supply of vitamins, although the sprouted gram contains a larger amount of vitamins and is more digestible than non-sprouted gram, for, the digestibility of gram starch with saliva is very low, whether it is sprouted or not.

Wilson, Ahmed and Mullick, after surveying the diets of some families and institutions in Calcutta, have concluded : (*a*) that the diets are poor in total and animal protein, total and animal fat, Ca and to a lesser extent P, (*b*) that the diets contain too low a percentage of dairy products and an excess of cereal, and (*c*) that

the minimum cost in Calcutta, at current prices, of a diet which approaches the western standard is about five annas per head.

Guha *et al* have found in the cooked diet actually consumed per day by an individual in an average middle class urban Bengalee family, the following mean values of Fe, CaO, P and protein (which is mostly of vegetable origin), 56·57 mg. of Fe, 0·96 gram of CaO, 1·27 gram of P, 53·45 gram of protein. The work would have been far more important if the edible portions of the cooked diet had been examined.

Aykroyd and Krishnan after investigating the effects of cheap well-balanced diets costing Rs.4 or Rs.5 a month per head (in the case of human) and containing articles of food which are available in India and are in conformity with dietetic habits, on the life and growth of rats, have concluded: (*a*) that it is difficult to devise a completely satisfactory cheap diet with milled rice as the main ingredient unless more milk and green vegetables are added, (*b*) that the average growth on all cheap diets is less than that on the stock diet, (*c*) that diets poorer in proteins and Vitamin B_2 are least satisfactory, although they contain sufficient amounts of minerals, Vitamin A or carotene and Vitamin C, and (*d*) that the ultimate test must be the effect of these diets on human beings.

Basu, Nath and Ghani, in investigating the biological values of green gram (*Phaseolus mungo*) and lentil (*Lens esculenta*) by the balance sheet method, have found: (*a*) that the biological values of proteins of green gram and lentils at different feeding levels are as follows:—

	5% protein intake.	11%	15%
Green gram	63	52	45
Lentils	53	32	25

(*b*) that the protein-value of green gram is 10·4 and of lentil 6·5 at a 10% level of intake (protein value is the actual amount of protein utilized per 100 grams of food ingested), and (*c*) that green gram is superior to lentil as a source of protein.

Basu, Nath and Ghani have also shown by rat growth tests: (*a*) that green gram is immensely superior to lentil for growth, (*b*) that rats on green gram ration containing 15% protein grow almost as efficiently as rats on a diet of milk and whole wheat, and (*c*) that rats on lentil ration show loss of fur, which can be remedied by the addition of 0·2% cystine to the diet.

J. C. Pal and B. C. Guha have made a nutritional study of some cooked Bengali dietaries and draw attention to the deficiency of calcium and protein, especially protein of animal origin.

B. B. Sarkar has written a paper on 'The need for a nutritional survey of the present day Indian diet'.

N. C. Bhattacharya has published a book in Bengali on nutrition and dietetics of the Bengalee.

N. M. Basu and S. R. Maitra have made investigations on the effects of humidity and high temperature on the NH_2 content of different samples of rice.

N. C. Bhattacharya and G. N. Bera have studied the calcium content of Bengali diet.

N. C. Bhattacharya and S. C. Sen have made studies on the hardening of Indian cheese.

McCay who was one of the earliest workers on Nutrition in India, in his memoir on '*Protein element in Nutrition*', dealt with the amount of protein required in nutrition. He made enquiries into the habits and physique of the different tribes and races of India and found that those who obtained a liberal supply of absorbable protein were superior to those who lived on a low protein diet. He was opposed to Chittenden regarding the great reduction of the protein content of the dietaries of mankind.

VII. Physiological Chemistry.

Sreenivasaya and Narasimhamurti have estimated maltose by the action of maltase. In mixtures with sucrose they find that this method accounts for 99·4% maltose. The method has been applied to estimate maltose in tissue fluid.

Sreenivasaya and Sastri have developed Galeotti's dilatometric method for estimation of action of hydrolytic enzymes. The results obtained in case of diastase, tannase, invertase and emulsion are identical with those obtained by chemical means.

Venkatgiri and Subrahmanyan found that barley soaked in water for 24 hours followed by steeping in a 0·1% solution of sodium nitrate and passing an alternating current of $4 \cdot 3 \times 10^{-3}$ amp. strength at 210 volts for 2 hours led to over 100% increase in the diastatic power of barley malt.

Narayanamurti and Ramaswami subjected the enzyme tyrosinase from Dilchos to ultrafiltration and found that it retained its activity. There was no acceleration in its action by addition of ultrafiltrate. Electro-osmosis failed to separate the enzyme into two components. These results do not support the view held by Hachn that tyrosinase can be separated by ultrafiltration into two inactive components, which become active on mixing together.

Sen studied the effect of narcotics on some dehydrogenases. He observed that narcotics had no effect on xanthine oxidase and Schardinger's enzyme, with regard to oxygen uptake or methylene blue reduction, but they had a marked inhibitory effect on succinic dehydrogenase. Some evidence regarding the identity of xanthine oxidase and Schardinger's enzyme from milk has also been adduced.

Dey and Sitharaman describe a new method of measuring peroxide content of tissue based on oxidation of hydroquinone to quinhydrone by peroxide in presence of hydrogen peroxide,

the quinhrydrone formed being estimated volumetrically. The possible sources of error have been discussed.

Sreenivasaya and Sreerangachari devised a new form of dilatometer, the main advantage being that enzyme and substrate could be mixed in the instrument automatically and so the instrument is suitable for studying the kinetics of reactions from the very start. The contraction due to the enzymic hydrolysis of one gram-molecule of the substrate is defined as *contraction constant.* The contraction constant of two systems, urea-urease and arginine-arginase, were found to be 24·13 and 5·02, thus enabling the use of this elegant method for the estimation of these substances in physiological fluids.

Venkatgiri studied the heat inactivation of pancreatic amylase. The inactivation is least near the optimum pH. The critical increment for the inactivation at pH 7·0 was found to be 41,000 cals. The data obtained do not give any clue as to whether the process is due to denaturation or hydrolysis.

Dey and Sitharaman find chow chow (secchium edule) to be a rich source of peroxidase. The optimum pH of the enzyme was found to lie between 4·8 and 5·2. A solution of KCN of the strength M/10000 completely inhibited the activity of the enzyme, while mercuric chloride had no effect up to a concentration of M/1000.

Narayana, Menon and Narayan Rao found that horse gram (*Dolichos biflours*) and Dhal (*Cajanus indicus*) contain the enzyme urease. Dolichos had an activity of 126 units as against 83·3 of Soya beans. Activity of Dolichos was greater at all temperatures between 40° and 90° C. Quantitative estimation of urea in solutions of known concentration and in biological fluids with Dolichos gave values in close agreement with those obtained by Soya Beans.

Basu and Nath isolated an enzyme preparation similar to papain from the milky juice of akanda, the optimum pH of the enzyme is 5 and optimum temperature 50°C. Hydrolysis of protein with the enzyme proceeds up to peptone stage. The authors isolated a white crystalline sulphhydryl compound (mp. 98° C.), which they consider to be a probable activator. KCN, H_2S and cystein were found to be activators.

Since the enunciation of the peptide hypothesis, the existence of the dicarboxylic amino acids is the form of their amides in the protein molecule has often been suggested. (1) Damodaran has succeeded in isolating asparagine from an enzymic digest of edestin by acting on the protein with pepsin, trypsin and yeast dipeptidase in succession and thus established its presence in protein molecule.

(2) Damodar and co-workers isolated glutamine from enzymic digest of gliadin, thereby giving additional evidence in favour of amide hypothesis.

Sreenivasaya and co-workers studied the tryptic digestion of proteins with his dilatometer. The volume change was found

to be proportional to the release of carboxyl or aminogroup which were respectively estimated by Willstatter's titration and Van Slyke's gasometric method. The volume change per milli-mol release of NH_2 was found to be characteristic of the stricture and amino acid make up of the protein. As the volume change accompanying hydrolysis is considerable, the accuracy attainable with dilatometer is greater than Van Slyke's method.

Sastri and Row reinvestigated the much discussed question of the presence of amylase in banana. They concluded that the enzyme is not present in the pulp but is confined to the skin.

Venkatgiri isolated an active preparation of amylase from sweet potato. Fivefold increased activity of the enzyme was found by dialysis. Inner portions of the tuber show greater activity than surface layer. He finds the optimum conditions for the inactivity of amylase from sweet potato (*Ipomea batatas*) lie between *p*H 5·5 to 6·0 and temperature 50–55° C. The amylase from sweet potato is mainly β amylose. A purified product 240 fold active gave negative test for protein and positive Molisch test. The author concludes that protein does not form any essential constituent of the structure of the enzyme.

Ghatak and Giri investigated the peroxidase from the fruits of *Tribulus terrestris*. The enzyme acts best at *p*H 5·3 to 5·5 and was stable up to temperature of 50° C. The effect of enzyme concentration and substrate concentration on the activity of enzyme was also studied.

Chopra and Roy investigated the proteolytic enzyme in cucumber (*Cucumis sativus*). The juice was found to contain a strong protease which is ereptic in nature and acts in slightly acid medium. The optimum temperature of reaction is 39° to 40° C. It was found to hydrolyze casein. The juice was found to contain rennetic activity.

The popular belief in North India that eating cucumber is associated with cholera is explained as due to the fact that erepsin reinforces the proteolytic activity of the cholera vibrio breaking down the proteoses and peptones formed from the intestinal epithelium with the production of increased amount of toxins.

Ramchandra Rau and Subrahmanya found that the aeration of barley during steeping greatly enhanced amylase activity. A control in which grain was steeped to the exclusion of air showed depressed activity.

Narasinha Acharaya from his study on barley malt and cholam (*Sorghum vulgare*) malt amylases concluded, that α amylase and β amylase are two enzymes, one possessing low saccharogenic activity with high amylolytic power, while the other with high saccharifying activity and low amylolytic power. It is difficult to obtain enzyme preparation with only saccharifying or only liquefying activity.

Sreenivasaya and co-workers studied hydrolysis of starch with amylase with their dilatometer and obtained a constant:

$$\frac{\text{c.mm. depression}}{\text{milli-mol maltose}} = 3\cdot$$

For inulin-inulase system the constant,

$$\frac{\text{c.mm. depression}}{\text{milli-mol fructose}} = 7\cdot9.$$

Giri found that different starches can be differentiated by the variation in colour, which they produce with N/100 iodine after they are hydrolyzed with amylase in agar-gel medium. The colours produced differ with the source of starch and the type of amylase employed. This affords an easy means of identifying different starches in food.

Sreenivasaya *et al* have studied the peptic and tryptic hydrolysis of casein and gelatine with the aid of dilatometer and have compared the results with those obtained by the determination of aminogroups liberated. They find that the ratio,

$$\frac{\text{c.mm. depression}}{\text{per milli-mol of } NH_2 \text{ liberated}},$$

is greater in the case of peptic than tryptic digestion.

Sreerangachar and Sreenivasaya have made a dilatometric study of the relative digestibility of globulins. They found that the dilatometric depression which in each case is proportional to the amino nitrogen released can be taken as a direct measure of digestibility.

Bhagavat and Sreenivasaya have extended the dilatometric study to follow the *in vitro* digestion of cow's milk. Their experiments reveal that the behaviour of casein particles in cow's milk toward trypsin does not appear to be different from that of casein particle in artificial solution.

Sastri and Iyengar explained the increased urease activity of leguminous seeds during germination as due to greater extractibility from germinated meal. The urease exist in the seeds in a 'desmo' condition which is rendered into the 'lyo' form during germination.

Giri and Dutta investigated the phosphatase system of the brain. There appear to be two phosphatases exhibiting pH optima 9·4–9·6 and 5·0 respectively. The ratio of the activities of the two phosphatases is constant for brains of animals of the same species. The alkaline phosphatase is activated by Mg, whereas acid phosphatase is not influenced by Mg-ions. The initial rate of hydrolysis of both enzymes varies with the substrate concentration in a manner predictable by the theory of Michaelis and Menten.

Giri found that human milk contains two distinct phosphatases exhibiting pH optima at 9·2 and 5·1 respectively. Colostrum is found to be very rich in phosphatase, containing about twice the amount found in normal milk. Towards the end of lactation period an increased amount of phosphatase is again observed.

Giri finds a phosphatase which splits sodium glycerophosphate and sodium hexosephosphate. It has been detected in human saliva and has been shown to be identical with urinary phosphatase.

Basu and Nath obtained an activase preparation of enzyme proteinase from milky juice of *Calotropis gigantea*. It can be obtained by half saturation and subsequent full saturation with ammonium sulphate. The enzyme is found to be activated by Glutathione and ascorbic acid.

Basu and Sarcar investigated the digestibility of rice starch from different varieties of Bengal rice grouped under 'aus' and 'aman' types, and found 'aus' type more easily digestible by Taka-diastase *in vitro*.

Basu and Mukerjee observed that 'aman' varieties are more easily digested by proteolytic and amylolytic enzymes than 'aus' varieties. The rice proteins are more readily digested by activated trypsin than by pepsin. Parboiling was found to increase the digestibility by enzymes. The starch from polished rice was found to be more easily hydrolyzed than non-polished grain.

Basu and Mukerjee extended the *in vitro* digestibility studies to pulses. The authors find that tryptic digestion of pulse protein proceeds more readily than peptic digestion. With both enzymes, the protein of lentil was found to be more readily digested than those of the green gram. Soya bean protein is as readily digested as that of pulses.

Bhagavat and Sreenivasaya followed *in vitro* digestion of globulin from cowpea and aconite bean by dilatometric and chemical methods. The authors observed that in globulins subjected to the successive action of pepsin and trypsin, higher values for digestibility are obtained than when they are subjected to the direct action of trypsin alone.

Dastur and Giri found that by *in vitro* digestion butter fat and coconut oil are almost equally digestible, while sesame and groundnut oil are much less digestible. Sodium tourocholate augments the digestion of butter fat and coconut oil by pancreatic lipase, while the digestion of sesame and groundnut oil is not affected by the salt.

Sreenivasan demonstrated the presence of a powerful oxidase specific to ascoroic acid in drumstick (*Moringa pterygosperma*). The enzyme acting at *p*H 5·3 oxidizes about 0·4 mg. of ascorbic acid completely and reversibly in 3 minutes. The action is inhibited by low concentration of cyanide and H_2S and destroyed completely by alcohol and partially by acetone.

Sreenivasan describes the preparation of ascorbic acid oxidase from press juice of the inner pulp of cucumber (*Cucumis sativus*) which is free from peroxidase system. The oxidase is present in both pulp and rind, while the peroxidase is located in the rind of the cucumber.

Ganguly has reported that both the venoms of Daboia and Cobra contain proteolytic enzymes capable of digesting gelatin, crystallized egg albumin, casein and fibrin. They also contain a lecithin splitting enzyme. A rennetic enzyme has also been observed to be present in cobra venom, but not in daboia venom. It is found that antivenine does not neutralize the proteolytic action of the venoms, while it neutralizes the rennetic action of cobra venom.

Ghosh studied the action of Cobra (*Naja naja*) venom on protein. With gelatin and egg-albumin as substrate, the protease of cobra venom had optimum activity between *p*H 7·8 to 8·0 And an enzyme promoting oxidation of hæmoglobin to methæmoglobin is also found to be present in the venoms of cobra and Russell's viper.

Basu and Mukerjee studied the question of identity of the Schardinger enzyme with xantheric oxidase. The authors inferred from their experiments on the effect of acidic and basic dyestuff on the oxidation of xanthine, salicylaldehyde and acetaldehyde by the milk enzyme, that the two enzymes are identical. The active group in the enzyme appeared to be acidic.

Sen and Bannerji carried out experiments on the synthetic enzyme carboxylase, and found that in complex proteins like gelatine, egg-albumin, etc., and nitrogenous bodies like urea and guanidine carbonate, organic ammonium salts are capable of bringing about the decomposition of pyruvic acid into acetaldehyde and CO_2.

Ranganathan and Sastri described a micro-method for the estimation of urea by the measurement of the change in conductivity resulting from the hydrolysis of urea by urease. The method gives reliable value for quantities as low as $0{\cdot}5 \times 10^{-5}$ g. of urea and can be applied to the determination of urea in various physiological fluids.

Singh and Mathur have devised a manometer for ascertaining the degree of purification of an enzyme preparation, for, by means of this apparatus the ratio of the volumes of O_2 absorbed by the final preparation and the original substance is obtained.

Sankaran and Rajagopal have shown that the electrometric method of Shaffer and Williams for determination of sugar is unsatisfactory in the case of small quantities of sugar, but if modified, as suggested by them, yields satisfactory results.

Chopra and Ray have devised a method for the colorimetric determination of lipoid P in blood and have pointed out : (*a*) that $CHCl_3$ does not extract the whole of lipoid P from blood, and (*b*) that the temperature at which the digestion is carried on and the acidity of the standard and digestion products have important bearings on colour development.

Goswami *et al* have devised a simple microchemical method for the estimation of glucose and have applied it successfully for the

estimation of glucose in blood. The method appears to be simpler than Hagedorn-Jensen's method.

Basu and Maitra have shown: (*a*) that rice stored in a humid atmosphere with high temperature is decomposed with the production of substances containing NH_2-radical; (*b*) that Dhenki-hulled rice shows greater resistance to the action of humid atmosphere and high temperature than milled rice; and (*c*) that milled rice becomes quickly porous, brittle, and infected under these conditions.

Giri and Dutta have investigated the nature and action of brain phosphates present in other organs.

Ranganathan and Sastri have devised a conductometric method for the micro-determination of urea, which gives reliable values for quantities as low as $0{\cdot}5/10^{-5}$ gram of urea. Banerjee and Mullick have devised a simple and reliable method of estimating glutathione in blood and tissues. They have shown that during the recovery period of the muscle of frogs, rabbits and cats after activity there is an appreciable rise in its glutathione content proportional to the previous period of activity and that *pari passu* liver glutathione values also increase. T. N. Seth has studied the effect of dilution of the lethal properties of a poison, and finds that up to a certain point an increase in the dilution of a poison which dissociates in solution causes a steady decline in its lethal properties. Beyond this point there is a limited range of renewed potency in which further dilution of the poison definitely enhances its lethal effects. Still further dilution, however, once again decreases the effectiveness of the poison. It is suggested that the lethal effects of a poison which dissociates in solution depend on the influence of both the undissociated molecules and the ions of the poisonous substances.

T. N. Seth and S. K. Ghosh Dastidar have made similar observations on the effect of dilution on the properties of an antiseptic.

N. J. Modi has shown that injection of milk in quantities used clinically produced stimulation rather than '*shock*'.

Ghosh and De observed that the proteolytic enzyme of Russell's viper venom had optimum activity at about *p*H 8·0 when gelatine and egg-albumin are used as substrate, and *p*H 7·0 wth casein as substrate. The peptidases contained in the venoms of cobra and Russell's viper are found to exhibit maximum activity between *p*H 8·2 to 8·4. The venoms contain trypsin inhibitors.

K. P. Basu and M. N. Basak have studied the metabolism of aminoacids in heart and in lung tissues.

VIII. Excretion.

S. L. Bhatia, J. D. Dundas, and S. M. Cooper made observations on the urea concentration test of Maclean and De Wesselow. They give normal standards for the test based on 38 normal subjects. The efficiency of the kidney of Indians to concentrate urea appears

to be as good as that of Englishmen from whom Maclean obtained his data. Six of the subjects were pregnant women. The test showed that normal pregnancy does not in any way impair the efficiency of the kidneys. There is less tendency to diuresis after administration of urea in Indians than in Englishmen. The average percentage of urea in urine is lower in Indians than Europeans, owing possibly to the smaller amount of protein in the diet. They discuss the value of the test in its application to certain medical and surgical conditions.

S. L. Bhatia has also reviewed all the more well-known tests employed to test renal function and has discussed their relative value and applicability in various clinical conditions.

Raghavachari has shown by studying the urine and blood pressure of 232 students (ages between 18 and 29), of whom 121 were vegetarians and 111 non-vegetarians, that age-for-age vegetarians have higher blood pressure than non-vegetarians, but the urine of vegetarians is clinically better than that of non-vegetarians.

Sokhey and Allen have studied the time-relationships of the changes in excretion of the inorganic phosphate in the urine, after ingestion of sugar and administration of insulin to normal and diabetic animals. Combination of carbohydrate and phosphoric acid play an essential rôle in the intermediary metabolism of carbohydrate. Administration of insulin to normal animals causes a fall in the inorganic phosphate of the blood and urine. As the blood sugar returns to the normal level blood phosphate rises again and the phosphate which was retained in the preceding period is swept out in the urine.

S. S. Sokhey, S. K. Gokhale, M. A. Malandkar and H. S. Billimoria have studied the effect of administration of sulphuric acid to fasting cats by feeding and by intravenous injection on the excretion of ammonia and fixed base.

They found that the greater part of the dose of the acid-fed is usually neutralized by ammonia, and the amount of the fixed base drawn upon varies from practically none to the equivalent of half the amount of acid absorbed. When the acid is injected intravenously and rapidly enough to cause hyperpnea, the amount of fixed base liberated is far in excess of what is needed to neutralize the acid, while a fall in ammonia excretion is observed. Results obtained by a subcutaneous injection pointed out that the ammonia production occurs even when the acid does not enter the body by way of the portal circulation. Further, the authors observe that the administration of acid does not cause any increase in phosphate excretion.

N. C. Datta has studied the absorption and excretion of tin in rats fed with food prepared in tinned brass vessels.

K. N. Bagchi and H. D. Ganguli have estimated the lead-content of urine and fæces, and the amount of arsenic in normal human tissues and excreta.

IX. Neuro-muscular System.

S. C. Devdatta has studied the diffusion of certain substances from muscles with a view to elucidate the structure of muscular tissue. He determined the equilibrium concentration of lactate in resting and fatigued muscles by diffusion and counter-diffusion methods. His experiments show that all the water of the muscle is available to dissolve lactate, as his values for the concentration of lactate in resting and fatigued muscles are in good agreement with those obtained by direct analysis of muscles by other workers. He and his assistants have performed experiments to show that the Indian frog muscle does not remain in equilibrium with a Ringer's solution in which concentration of sodium chloride is 0·71% for resting muscles and 1·2% for fatigued muscles.

B. B. Dikshit has observed that extracts of cat's and rabbit's brains have a physiological action on the blood pressure and intestines exactly similar to that of acetylcholine, and further, that some effects produced by stimulation of the central end of the vagus nerve in an anæsthetized animal were similar to those produced by injection of small quantities of acetylcholine in the brain ventricles. He subsequently found that the substance present in the brain extracts was acetylcholine. Its concentration varied in different parts of the brain and was highest in the basal ganglia. He suggested that chemical transmission such as seen in the peripheral nervous system may be present in the central nervous system as well. Later he showed that irregularities of the heart could be produced by excitation of hypothalamic centres, and also found that acetylcholine injected into cerebral ventricles produced a cardiac arrhythmia as was caused by stimulation of the central ends of the vagus nerve in cats. He further observed that acetylcholine had an action on the 'sleep' centre in the hypothalamus, for when injected in small amounts into brain ventricles it produced a condition very clearly resembling sleep.

Dikshit has also been working on choline esterase of the blood. He finds that there is a close relation between the acetylcholine content of the brain and the choline esterase of the serum. He estimated the acetylcholine content of brain of different species of animals and the choline esterase of their blood, and found that whenever the acetylcholine content is high the esterase content is also high. Dikshit and Mahal have shown that choline esterase concentration of the blood is reduced by toxemia produced by inoculation of plague cultures or Haffkine's plague vaccine.

B. N. Prasad has studied the carbohydrate metabolism of gut muscle. He finds that the isolated gut muscle contains only about 0·25% carbohydrate available for glycolysis, and that in presence of oxygen it oxidizes about 1 mg. carbohydrate per g. per hour. In presence of glucose it produces considerable quantities of lactic acid both under ærobic and anærobic conditions. The

deeper portions of the muscle probably do not contain an adequate oxygen supply even in oxygenated fluid. Under anærobic conditions about 2 mg. glucose per g. per hour is hydrolyzed. Sodium iodoacetate (1 : 10000) inhibits glycolysis of glucose in the Ringer's fluid in contact with the gut muscle. Periodic electrical stimulation increases the glycolysis by about 12%.

He has studied the mechanical activity of gut muscle under anærobic conditions. He finds that asphyxial arrest of the mechanical movements of this muscle is not due to accumulation of acid but to exhaustion of its labile carbohydrate store. The mechanical experiments confirm the biochemical findings that the gut muscle has only a small reserve of available carbohydrate. It probably utilizes a mixed diet of carbohydrate and non-carbohydrate material in ærobiosis. Its activity is maintained best when it is supplied with both glucose and oxygen. Iodoacetic acid-poisoned gut muscle has a very limited activity under anærobiosis : this suggests a small phosphagen content.

He also finds that gut muscle driven by rhythmical electrical stimulation and arrested under asphyxia can still contract in response to acetylcholine. Adrenalin has a powerful inhibitory action on the activity of the muscle asphyxiated in presence of glucose. The muscle poisoned with iodoacetic acid responds in a normal manner to adrenaline and acetylcholine. Its response to these two substances is not markedly influenced by changes in the metabolic processes of the tissue.

Basu has succeeded in taking uniform genesis of tetanus curves by equalizing make-and-break shocks obtained by a tetanus spring according to the principle of Helmholtz. He has devised a method of perfusion of frog's heart, in which the pressure of fluid in the course of perfusion remains unaltered. He has also improved the method of taking tracings on a drum, so that the friction of the lever against the drum remains constant. He has shown by these improved methods that urea-stibamine is toxic to frog's heart at the dose corresponding to the human dose, but that neo-stibosan has no toxic effect either at the dose corresponding to the human dose or at two and three times that dose.

Chopra and Das, by introducing certain modifications in Mathew's Oscillograph, have succeeded in getting the following advantages over the latter instrument : (*a*) a comparatively large movement of the mirror, (*b*) no hysteresis, (*c*) no residual effects, (*d*) a very short time-lag of the order of 0·0001 sec., and (*e*) the instrument is electrically unbreakable.

A. Gaffar has studied the mechanism of iodoacetate poisoning of muscle diffusion of lactic acid and iodide into and out of the voluntary muscles of frog.

W. Burridge in his book 'Alcohol and Anæsthesia' brings the action of anæsthetics into line with the new doctrine of the rhythmical activity of living neural structures.

Narindra Singh has made studies of dreams, which have an interesting bearing on some Freudian hypothesis.

S. L. Bhatia has studied the problem of 'Conditioned Reflexes' and has pointed out that here there is a point of contact between Physiology and Psychology.

B. B. Sarkar has made observations on the depressor nerve in the rabbit and finds that it is connected, in part at least, with a special collection of ganglion cells in the vagus distinct from the ganglion of the trunk.

B. Narayana and H. N. Banerji have studied the action of Ergotamine on the isolated œsophagus, small intestine, rectum, and bladder of the frog. This drug seems to have a stimulant action on the plain muscle of these isolated tissues, and does not abolish the inhibitory action of adrenaline.

N. M. Basu and R. Ghosh have studied the influence of Ca, K, curare, cobra-venom, and ajmaline group of alkaloids on the fatigue of skeletal muscles of frog.

X. The Endocrines.

B. T. Krishnan has studied the influence of adrenaline, pituitary extracts, and insulin on the movements of intestine. He confirmed the findings of other observers regarding the excitatory effects of adrenaline under conditions of increased parasympathetic tone. Pituitrin and its active principles have an initial augmentative effect followed by sudden or gradual inhibition on the bowel of the cat. The effects vary in different animals. Insulin stimulates the bowel indirectly by lowering the sugar content of blood.

S. Krishnan has shown that insulin in the dose of one-millionth of a unit stimulates the heart, but in larger doses depresses it. The effects of adrenaline last much longer when insulin is present, although they become maximal after longer time than usual in such circumstances.

Mukerjee finds that if a suspension of insulin-phosphotungstate containing proper amounts of phosphotungstic acid be given by mouth to a diabetic, the sugar content of blood is rapidly reduced owing to accelerated oxidation of sugar in blood, as this compound has been shown to behave like a peroxidase. Further, the output of urine is also increased.

D. M. Telang and D. B. Shirsat made some observations on the effect of oral administration of insulin phosphotungstate upon the sugar content of rabbit's blood. They found no material reduction in the blood sugar content as the result of this mode of insulin administration.

Palit and Dhar have shown (*a*) that appreciable oxidation of glucose takes place in air in presence of solid surfaces, (*b*) that in presence of glutathione the oxidation is increased : and it is further increased in presence of both phosphate and glutathione, (*c*) that,

similarly, insulin increases oxidation, more so when phosphate is also present, (*d*) that a mixture of insulin and glutathione acts better than either insulin or glutathione alone, (*e*) that oxidation in a mixture of insulin and phosphate or glutathione increases with the concentration of $FeCl_3$ in the mixture and is further accelerated in the presence of traces of Cu or Mn, either singly or in mixture, but is retarded if the latter is present in large amounts, and (*f*) that reducing agents like glutathione, chlorogenic acid, ascorbic acid, internal secretions, etc. act as inductors taking up O_2 directly from air and thus induce the oxidation of food materials.

E. W. H. Cruickshank and S. Prasad have studied the action of insulin on the free muscle sugar of the normal and diabetic heart.

E. W. H. Cruickshank, B. Narayana, and D. L. Shrivastava have made an experimental study of the action of insulin on normal and diabetic hearts. They find amongst other things that insulin in the presence of excess of available sugar will effect storage of sugar as glycogen in the heart muscle. In the diabetic heart insulin invariably causes a reduction in glycogen.

K. Venkatashalam and A. N. Ratnagiriswaran have demonstrated that anterior pituitary extract produces marked hyperglycæmia in cats, the effect being enhanced by vagi section or atropinization. Gonadal extracts have an opposite action, reducing the blood sugar in normal animals, and also counteracting the hyperglycæmia induced by the administration of anterior pituitary extract. The effects observed with the latter have been proved to be due to its depressant action on the vagus. The possible utility of gonadal extracts as antidiabetic remedies has been indicated.

S. L. Bhatia and J. D. Dundas made observations on the spleen adopting Barcroft's technique of withdrawing it from the abdomen and fixing it externally on the abdominal wall under aseptic conditions. Its blood supply remains intact. The 'extracutaneous spleen' is very suitable for studying changes in volume that occur in it as the result of exercise, hæmorrhage, etc.

G. R. McRobert has published observations on the size of the spleen.

M. A. Basir has studied the histology of the spleen and suprarenals of *Echidna*. He is studying the pressure required to open up the ellipsoids in spleen, when fluid is injected from the splenic vein, also the effects of acetylcholine and adrenaline on this back pressure. His work on the comparative study of the vascular supply of the pituitary body is also in progress. He has already published a paper on the vascular supply of the pituitary body in the dog, as well as on the structure and significance of the hypophysioportal system.

Sankaran studied the iodine content of the normal thyroid of the albino rats and found that it had the value of 0·018% iodine content was found to be directly proportional to the thyroid weight.

No significant difference in the iodine content of the thyroid between the two sexes could be found.

McCarrison found that deficiency of Vitamin A caused proliferative changes in the mucous membrane of the trachea accompanied by distension of the thyroid and backward growth of the lateral lobes of the latter.

McCarrison and Newcomb found that rats fed on diets deficient in Vitamin A and low in iodine content, and kept under insanitary conditions, developed compensatory hypertrophy of the thyroid, while in animals kept clean there was no such symptoms. Unhygienic conditions also produced enlargement of spleen and liver which was not rectified by ingestion of extra iodine.

McCarrison further finds that besides deficiency of Vitamin A another factor exists, suspected to be of an infective nature, which is responsible for the incidence of lymph-adenoid-goitre. High protein diets with excess of fat-soluble vitamin stimulated excretion of urine.

McCarrison investigated the goitrogenic action of cabbage on rabbits. The goitre-producing potency of cabbage varied with season. The effect of steaming on goitrogenic potency was found to be irregular. Carrots, sprouted gram and fresh cut grass were shown to possess antigoitrogenic properties. Iodine manganese chloride, thymol, and thyroxine administered with cabbage diet had a protective action. Sodium chloride, radiostoleum and bran enhanced the goitrogenic action of cabbage. It is suggested that radiostoleum with ca[illegible] or gradua[illegible] causes goitre by hypertrophy of the gland, which is otherwis[illegible] different [illegible]n lymphadenoid goitre it is the further degeneration of an inefficient gland tending towards lymphocytic infiltration and atrophy of the parenchyma cells. In one case, goitre may set in owing to overstrain, while in another it is degenerative from the beginning.

McCarrison and co-workers did not observe any difference in iodine content of urines of goitrous and non-goitrous persons in Gilgit. The urinary excretion of iodine was found to be generally very low in both the groups which was in conformity with the low iodine content of the soils. They did not find any relation between urinary excretion of iodine and occurrence of disease.

An important contribution to the subject of goitre is embodied in a memoir entitled 'The life-line of the thyroid gland' by McCarrison. The memoir deals with statistical criteria of the normal size of the thyroid gland and the extent to which it is influenced by diet, sex, sexual activity, season, sanitary conditions, and iodine supply. The importance of the thyroid gland as an indication of the dietetic deficiencies is very clearly brought out in the memoir. Goitre is likely to occur whenever a dietetic deficiency interferes with the normal process of growth. Evidence has been adduced to show that iodine-theory of goitre cannot be sustained. Iodine deficiency may contribute to goitre but it is not

the cause of it. The environmental deficiency of iodine and the individual deficiency of iodine are the common result of some undiscovered factor affecting both.

McCarrison made another important contribution dealing with the effect of insanitary condition on the thyroid gland and other glands of the body.

Stott emphasized that factors other than iodine are the cause of endemic goitre. He attributes the endemic colloid goitre of United Provinces to an excessive intake of calcium. Stott is positive about a relation existing between the calcium of the water-supplies and goitre, and hence attributes the goitre to an imbalance between the calcium and the iodine intake, a finding in conformity with McCarrison's experimental work on animals.

Malhotra finds that iodine in organic combination is superior to inorganic iodine in the prevention of endemic goitre. Iodine from plants is better than that from animal sources.

McCarrison demonstrated the existence of a 'goitre-noxa' in association with insanitary conditions. Albino rats fed on a non-goitrogenic but ill-constituted diet became goitrous when living under insanitary conditions. The greater the degree of insanitation the greater the size of goitre produced by it. A well-constituted diet afforded albino rats subjected to the above conditions of insanitation a high degree of protection against hyperplastic goitre.

The 'goitre-noxa' was found to be water-soluble and of a dual nature, a hyperplasia-producing factor and an adenoma-producing factor. The former was counteracted by a well-constituted diet and by iodine, while the latter was not.

McCarrison found soya bean and groundnut to be goitrogenic in the absence of Vitamin A bearing ingredients. The thyroid enlargement occurred despite the ingestion of a large amount of iodine.

McCarrison and Sankaran employed tissue culture technique to investigate the nature of the toxic principle in the goitre-noxa associated with certain insanitary conditions. They find that the toxic substance is water-soluble; when present in culture medium in relatively high concentration it completely inhibits the growth of thyroid tissue *in vitro* in moderate concentration. Its inhibitory action on the growth of the tissue is less marked and that in still lower concentration (1 in 500,000) it exercises a markedly stimulating action on the growth of these cells, without seeming to hasten degenerative changes.

Stott and Das Gupta continued their investigations on the distribution of goitre in United Provinces. The authors in one of the contributions deal with clinical studies on endemic goitre, sub-thyroidism, cretinism in super-endemic area of Gonda and Gorakhpur districts in U.P. The second paper deals with ætiology of goitre in the same locality. The authors observe that diet does

not play a part in the production of goitre. There is a considerable volume of evidence to show that goitre is a water-borne disease.

B. B. Sarkar has studied the effects of thyroidectomy on the bone-marrow of rabbits, and of thyroid feeding on the bone-marrow of thyroidectomized rabbits. With R. K. S. Lim and J. P. H. Graham he has also studied the effects of thyroid feeding on the bone-marrow of these animals.

A. L. Mudaliar, K. Venkatachalam, and A. N. Ratnagiriswaran describe the influence of the thyroid gland in controlling the activity of the posterior pituitary gland. The possibility of hypothyroidism being a cause of habitual abortion has been suggested and corroborated by means of clinical evidence.

S. L. Bhatia has described the interrelationships of hormones. Some of them mutually stimulate, others inhibit each other. Accurate knowledge of these interrelationships would help us to recognize the endocrine organ primarily involved and to distinguish it from others secondarily affected. All the hormones are intimately associated with each other. There is thus an integration of hormonal functions by virtue of this mutual interdependence. The mechanism effectively supplements the integration through the nervous system.

XI. Histology.

B. N. Chatterji and E. W. H. Cruickshank made a comparative study of the spleen of various vertebrates with reference to the bone marrow and the blood. In the frog the spleen is the sole organ for erythropoiesis, because bone marrow in the species is exceedingly poor in erythroblastic elements. The erythrogenic function of the spleen is gradually shared by the bone marrow throughout the submammalian series. The lymphocytic content of the spleen is one of the main controlling factors of the lymphocytic content of the blood. Throughout the mammalian series, a gradual increase in the percentage of polymorphs in the blood is seen to be associated with a gradual increase of the total percentage of polymorphs and neutrophilic transitional myelocytes in the bone marrow. On the other hand, the paucity of the neutrophilic transitional myelocytes in the marrow of aves and reptilia is corelated with a marked dearth of neutrophil leucocytes in the circulating blood.

Sarcar has devised a method of staining with ammoniated solution of tannin for bringing out neurofibrils and nerve cells. By this method the course of even the finest neurofibrils can be traced in serial sections. He has also described a method of staining with Orange G. and Aniline blue.

Sarcar, Sen and Bera have devised a method of preparation of tissues for paraffin infiltration and embedding, which would be very useful in the tropics, especially when the temperature of

air is high, and when paraffin of high melting point is required for embedding.

Aykroyd and Sankaran have found that if embryonic nerve tissue is cultured in plasma from fowls and rats fed on (*a*) a good mixed diet, (*b*) a diet deficient in Vitamin A and (*c*) a control diet similar to (*b*) but containing cod-liver oil, excellent growth takes place in plasma and poor growth in deficient plasma. The growth response in control plasma lies between these two extremes.

Chopra, Das and Mukherjee have shown that cobra venom in higher dilutions stimulates growth of tissues *in vitro*, while at lower dilutions it inhibits growth.

A. Subba Rao is carrying on work on the structure of the ovary, fallopian tube and uterus of *Loris*. He has published work on the morphology of Lemuroidea.

Finally I may say, that my Presidential Address on '*Physiology in India*,' delivered before the section of Physiology, Indian Science Congress, Hyderabad, Deccan, in 1937 contains an account of Physiology in this country in its true perspective, giving an account of its past and its future lines of development.

My best thanks are due to the workers in different parts of India and to my colleagues in the Physiological Laboratory, Grant Medical College, Bombay, for their valuable help and co-operation in the preparation of this paper. I am specially thankful to Bt.-Colonel R. N. Chopra, I.M.S., for his help in writing the section on Pharmacology.

XII. Pharmacology.

The systematic study of pharmacology in India may be said to have begun in 1921 when a chair on the subject was established at the Calcutta School of Tropical Medicine. Previous to that, pharmacology was not included in the curricula of the medical schools and colleges in India and investigations in this field were conspicuous by their absence. Admirable attempts were no doubt made from time to time by individual workers to study the action of well-known indigenous remedies, but their efforts were limited to sporadic observations and in many cases, to uncontrolled clinical trials. The study of indigenous anthelmintics by Caius and Mhaskar, though mainly conducted on chemical lines, was the only pharmacological research of the earlier days which is worthy of note.

During the 16 years which have elapsed since the inception of the Calcutta School, pharmacology has gradually been recognized as a fundamental and basic science of great importance in the rational study of therapeutics and clinical medicine, and several chairs of pharmacology have been established in different parts of India. This has stimulated research and within recent years a number of papers have emanated from the laboratories in Calcutta,

Bombay, Punjab, Madras, and elsewhere. The School of Tropical Medicine in Calcutta and the Haffkine Institute in Bombay, however, have played the major rôle in the progress of pharmacology in India during the period under review. From both these centres, a steady stream of papers have been published bearing on various aspects of physiology, pharmacology, and biochemistry. The work at the Haffkine Institute was suspended for a few years, but it is gratifying to note that it has been restored under the direction of Dr. B. B. Dikshit. The School of Tropical Medicine under the leadership of Bt.-Colonel R. N. Chopra, I.M.S., has, however, carried on its work uninterruptedly and has built up a very fine record of research work.

A considerable amount of work both basic and applied in character has emanated from the department of pharmacology at the School and elsewhere. It is not possible to discuss it in detail but some of the salient features of the investigations carried out will be mentioned here. Emphasis appears to have been laid on applied and clinical research and many of the problems studied have a direct bearing on the practical aspects of diagnosis and treatment of diseases. The results of these investigations have been mostly published in the *Indian Medical Gazette* and in the *Indian Journal of Medical Research*, and the reader is referred to the original publications for detailed information. It will be convenient for purposes of description to classify the subjects studied under several heads.

(*a*) *Researches on the pharmacology and toxicology of remedies of special importance to medical practice in India.*

Cinchona Alkaloids

One of the earliest researches undertaken in the School was in connection with the pharmacology of the different alkaloids of the cinchona bark with a view to determine whether some of them were as effective as quinine in the prophylaxis and treatment of malaria. If the residual alkaloids after extraction of quinine could be used in malaria, the cost of treatment would naturally be considerably reduced. A large amount of pharmacological and clinical work extending over several years was carried out on cinchonine, cinchonidine, quinine, quinidine, cupreine, and hydrocupreines. The efficacy of the residual alkaloids was conclusively demonstrated and the advantages that might be gained by employing them in mass treatments were pointed out. This work is partly responsible for the inclusion of cinchona alkaloids in the British Pharmacopœia in the form of 'totaquina'. Their value in the treatment of malaria has been amply corroborated by the Malaria Commission of the League of Nations and it is now recommended as a standard remedy for malaria.

Emetine

Emetine has been used in the treatment of dysenteries by practitioners in India and its toxic manifestations were not sufficiently appreciated. An investigation into the pharmacology and toxicology of emetine was carried out and it was shown that emetine had a selective toxic effect on the parenchyma of the heart muscle. If the dosage exceeds the optimum level, toxic symptoms especially referable to the heart supervene. Great caution therefore is needed in its administration.

Organic derivatives of Antimony

In view of the importance of the antimony compounds in the treatment of kala-azar, investigations into the pharmacological action of the organic derivatives of antimony were undertaken. The pentavalent compounds depress the circulation and respiration but stimulate the reticulo-endothelial tissue of the spleen, liver, and bone-marrow, resulting in increased leucocytosis and phagocytosis. Further, a rhythmic contraction of the spleen is induced which squeezes out and disintegrates many cells laden with leishmania parasites. The beneficial influence of the antimony compounds in kala-azar is probably largely brought about through these mechanisms. An interesting development of this work is the discovery of Chopra's test for the diagnosis of kala-azar. The test depends on the fact that a heavy flocculent precipitate is thrown down when a solution of urea stibamine is added to the clear serum from a kala-azar patient. This test is easily performed, is very sensitive, and renders early diagnosis of kala-azar possible in 85 per cent. of cases. It has been of great help in the differential diagnosis of malaria and kala-azar in some of the endemic areas.

Indian Artemesia and Ephedras

A large amount of work was conducted on the botanical, pharmacological, toxicological, and therapeutic aspects of the Indian species of *Artemesia maritima* and Ephedras. Excellent quality of santonin can be obtained from Indian Artemesia growing in Kashmir. Indian Ephedras grow in great abundance in certain parts of the Himalayas and give a good yield of the alkaloids. Although pseudo-ephedrine predominates in some species, others give good yield of ephedrine. It was also shown that pseudo-ephedrine is pharmacologically as active as ephedrine in many respects, is less toxic than ephedrine, and is even a better cardiac stimulant than ephedrine.

Anthelmintics

Considerable attention was paid to the pharmacological and toxicological properties of a number of anthelmintics, chief amongst which were carbon tetrachloride, santonin, and oil of chenopodium. Carbon tetrachloride was found to be toxic to the liver and this toxicity was not reduced by the administration of sugar. In suitable doses, however, it could be safely administered, provided the diet contained a plentiful supply of proteins and carbohydrates and was not too rich in fats. Besides such isolated observations on

individual anthelmintics, a large volume of data based on laboratory, hospital, and field work on various aspects of the anthelmintics problem was collected and published in the form of a book entitled '*Anthelmintics in Medical and Veterinary Practice*' by R. N. Chopra and Asa C. Chandler, published by Williams and Wilkins & Co., Baltimore, America.

(*b*) *Researches on the venoms of Indian snakes.*

The snake venom enjoyed a great reputation in India as a very potent remedy in cardiac failure and as a general stimulant. A study of the pharmacological action of snake venoms was therefore started in 1931, and has been continued since then. Venoms from cobra, Russell's viper, and saw-scaled viper were studied from the pharmacological, toxicological, biochemical, and therapeutic viewpoints. Contrary to popular belief, the venoms do not seem to possess any stimulant action on the heart. Cobra venom, however, has been useful in relieving pain in cancer and in exerting a beneficial influence in chorea, insanity, and epilepsy. How it brings about this effect is not yet explained.

(*c*) *Researches on the physical properties of blood sera in health and disease.*

In order to explain many pharmacological and toxicological phenomena which arose in the course of other researches, work was undertaken to study carefully the physical and biochemical properties of blood sera in healthy individuals and in different pathological states. Much interesting and instructive data have been collected in this field and have thrown a flood of light on many hitherto unexplainable and obscure problems. In general, pathological sera show a high viscosity, low surface tension, and diminished buffer action. The electrical properties also show significant changes from the normal ranges. In kala-azar, the serum proteins undergo marked changes and the viscosity rises much more than in any other disease like tuberculosis, syphilis, or leprosy.

(*d*) *Researches on Indian indigenous drugs.*

A very important research programme which had a far-reaching influence on the scientific and economic aspects of Indian medicine was the investigation, on modern scientific lines, of the claims of the rich materia medica of the Ayurvedic and Unani systems of medicine. In 1924, a programme of research was decided upon and this programme has since been strictly adhered to. The main purposes of this research are as follows :—

1. To investigate the possibility of manufacturing the drugs official in the pharmacopœias of Great Britain and

the United States from Indian sources, thus reducing the present enormous cost of importing these drugs from foreign countries.

2. To investigate the possibility of utilizing Indian plants and drugs whose active therapeutic principles closely resemble those of the official pharmacopœial drugs.
3. To investigate the remedies used in the indigenous systems of medicine in India which have an established reputation under strictly scientific and experimental lines, in order to assess their real value.
4. The working out of an Indian Pharmacopœia, consisting of drugs and remedies mostly of Indian origin, in order to render India almost independent of outside resources.

During the last 12 years this inquiry has done a considerable amount of work which has not only received local appreciation but international recognition. The Departments of Pharmacology and Chemistry of the School is now considered an authority on all questions in connection with the chemistry, pharmacology, and therapeutic uses of the Indian indigenous drugs. A team of botanists, chemists, pharmacologists, and clinicians are co-operating in this work and the plan of attack has been to study, first, the chemical composition of the drugs in order to determine the nature of the active principles contained in them. The pharmacological action and toxicity are then worked out on laboratory animals. When these laboratory findings have reached a stage when a definite opinion as to the value of the remedy can be formed, the drug is given a clinical trial in the special research hospital attached to the School of Tropical Medicine. A drug is only considered worthy of being introduced and recommended for clinical practice when it has passed satisfactorily through all these tests. It will not be possible here to indicate the extensive work that has been done. A complete list of all the indigenous drugs so far investigated is given below. Though no epoch-making discoveries have been made, this inquiry has shown that only a very limited number of indigenous remedies deserve the reputation they have earned as cures and that quite a large proportion of them are absolutely worthless and have probably crept into the system through tradition and folklore. On the other hand, as a result of this work many of the pharmacopœial drugs and allied species grown in India have been brought into use in the manufacture of pharmaceutical preparations in this country. The work done in this connection up to 1932 has been published in a book entitled the 'Indigenous Drugs of India' by R. N. Chopra, published by the Art Press, Calcutta. Further work will be included in the edition which is now due.

Abhrak vasman.
Abroma augusta.
Acanthus ilicifolius.
Aconitum ferox.
Aconitum lycoctonum.
*Aconitum napellus.
*Aconitum napellus (Mohri).
Adhatoda vasica.
Alangium lamarckii.
Alstonia scholaris.
Antiaris toxicaria.
Aristolochia indica.
*Artmesia maritima.
*Atropa belladonna.
Banga bhasman.
Berberis aristata.
Berberis asiatica.
Boerhaavia diffusa.
Bryophyllum calycinum.
Butea frondosa.
*Camphor.
Cæsalpinia bonducella.
Carica papaya.
Cephalandra indica.
*Chenopodium ambrosioides.
*Citrullus colocynthis.
Colochicum luteum.
Coptis teeta.
Corchorus capsularis.
Crocus sativus.
Cucumis sativus.
Dæmia extensa.
Dendrobium macraei.
Digitalis lanata.
*Digitalis purpurea (Indian).
Ephedra pachyclada.
*Ephedra vulgaris.
Erythrina indica.
Eugenia jambolana (seeds).
*Glycyrrhiza glabra.
Gmelina arborea.
Gold kusth.
Gratiola monniera.
Gymnema sylvestre.
Holarrhena antidysenterica.
*Hydnocarpus anthelmintica.
*Hydnocarpus wightiana.
*Hyoscyamus muticus.
*Hyoscyamus niger.
Hygrophila spinosa.
Inula racemosa.
Ipomœa hederaceæ.
Iris root.
Juniperus communis.
Juniperus macropoda.
Lathyrus sativus.
Lavatera ashmiriana.
*Lobelia nicotianæfolia.
Makaradhaja.
*Mentha arvensis.
Menthol.
Moringa pterygosperma.
Musk.
Papaver somniferum.
Paspalum scrobiculatum.
Phyllanthus urinaria.
*Picrasma quassioides.
Picrorhiza kurrooa.
Pistacia integerrima.
Plantago ovata.
Podophyllum emodi.
Pongamia glabra.
Premna integrifolia.
Psoralia corylifolia.
Psychotria ipecacuanha.
Rauwolfia serpentina.
Rheum emodi.
Sansevieria zeylanica.
Saraca indica.
Saussurea lappa.
*Scilla indica.
Sida cordifolia.
Silajit.
Solanum indicum.
Soymida febrifuge.
Swertia chirata.
Sweth parpati.
Tabernoemontana coronaria.
Taraktogenos kurzii.
Terminalia arjuna.

* Those with an asterisk are official in the Pharmacopœia.

Terminalia chebula.
Thevetia neriifolia.
Tinospora cordifolia.
Tribulus terrestris.
Tylophora asthmatica.
*Urginea indica.
*Valeriana wallichii.
Vernonia (Serratula) anthelmintica.
Vitex peduncularis.
Xanthoxylon acanthopodium.

(e) *Researches on drug addiction in India.*

That drug addiction is a menace to the physical, mental and moral well-being and development of the individual and therefore, of the whole nation is sufficiently well recognised to-day and the League of Nations have repeatedly made attempts to stop drug addiction in every form in all parts of the world where it exists. Like other countries, India has her own problem of drug addiction but it is more widespread than in many other parts of the world. This will be evident from the fact that whereas in other civilised countries, the drug addiction rate of the population is from 0·1 to 0·2 per cent, in India in some areas, the rate may be from 1 to 3 per cent. The whole subject is of vital importance from the social, economic, and health points of view, and an investigation into the various aspects of the problem was urgently called for. Since 1926, a large volume of work has been done both in the laboratory of the Tropical School as well as in the field. The drugs of addiction so far studied include opium, alcohol, *Cannabis indica*, cocaine, chloral hydrate and barbiturate. In 1895, a Royal Commission of experts reported that moderate indulgence in opium eating in India led to no injurious effects. This conclusion has been definitely disproved now and there is no doubt that opium eating produces in Indians deleterious actions similar to those produced in Europeans. Laboratory studies on addiction were chiefly directed to observations of the effects of addiction on human beings as well as on laboratory animals and to find measures to counteract the 'withdrawal' or abstinence symptoms. Several methods of treatment which have been advocated from time to time were tried but administration of lecithin injections appeared to give the most promising result. The field studies included extensive general surveys of the extent of addiction of opium, hemp, cocaine, etc., in the various provinces of India. Opium addiction is definitely decreasing but cocaine addiction, which is of comparatively recent origin, shows signs of increase. The study of drug addiction in India has revealed many interesting facts which are of importance from medical and sociological points of view.

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(g) *Biological standardization of drugs on the Indian market.*

Early in the course of the investigations on drugs at the School of Tropical Medicine, it was evident that a state of absolute chaos exists with regard to the drug trade in India. A large number of drugs on the market were biologically tested in the department of pharmacology and were found not to possess the therapeutic activity that they are alleged to have. The high atmospheric temperature, combined with a high degree of humidity produce deterioration during storage, even of some of the products of reliable English and American firms. Those manufactured in India, including some of the potent compounds of arsenic and antimony, are subject to no control whatever by State and consequently they vary a great deal in strength. In the absence of any legislation to prevent drugs of poor quality being sold freely to the public, the Indian market is glutted with spurious products and this constitutes a serious menace to public health. In 1930, a Drugs Enquiry Committee was appointed by the Government of India under the Presidentship of Bt.-Colonel R. N. Chopra, C.I.E., K.H.P., I.M.S., to go fully into the question of drug adulteration in India. This committee emphatically brought out the urgent need for the standardization of drugs and for some legislative measure to control drug trade in India. It is gratifying to note that as a result of the recommendations of the Drugs Enquiry Committee, the Government of India have taken steps to introduce a new bill to control the import of adulterated drugs into India. A Bio-chemical Standardization laboratory has also been recently established under the direction of Bt.-Colonel R. N. Chopra to analyse and assay the purity and potency of medicinal preparations in the Indian market. It is hoped that these steps will go a great way in remedying the evil of drug adulteration and spurious drug trade in India.

XIII. Bibliography.

Many references on the subject would be found in the Biochemical and allied Research in India, 1930, 1931, 1932, 1933, 1934, 1935 and 1936 (Publication of the Society of Biological Chemists, India), and in The Proceedings of the Indian Science Congress. The papers are scattered in numerous journals, of which the most important are: The Indian Journal of Medical Research, The Indian Medical Gazette, The Quarterly Journal of Experimental Physiology, The Journal of Physiology, The Journal of Anatomy, The Biochemical Journal, The Journal of The Indian Institute of Science, Current Science, Nature, Proceedings of the Indian Academy of Science, The Calcutta Medical Journal, Patna Medical Journal, The Journal of the University of Bombay, The Medical Bulletin, The Journal of the Mysore University, Journal of the

(f) Chemotherapeutic studies on anti-malarial and anti-dysenteric remedies.

The effectiveness of a number of natural and synthetic anti-malarial remedies, e.g., quinine, atebrin, plasmoquin, malarcan, tebetren, paludex, etc. was tested on human malaria and in monkeys infected with a hæmoprotozoon called *Plasmodium knowlesi*. This plasmodium appears to be closely related to the parasites of human malaria and hence the results obtained from these observations could be readily applicable to man. Considerable amount of interesting work on different aspects of malaria therapy has been done on this experimental animal. The concentration attained by the new anti-malarial remedy, atebrin, in the circulating blood at different intervals of time in relation to parasite count was worked out. A new and comparatively easy method for the estimation of atebrin in small quantities of blood was devised and it was shown that the highest concentration of atebrin occurs between ½–6 hours after injection. The number of parasites diminishes markedly during the period when the concentration of the drug in the blood is highest. The same relationship does not hold good in the case of quinine and therefore it is probable that the nature of action of these two anti-malarial remedies is probably different, atebrin acting directly on the parasites whereas the other (quinine) exerting its influence through some defence mechanisms of the body. It was further shown that atebrin had an exceptionally powerful destructive action on both the schizogony and gametogony of ape malaria, a small dose (0·5 gm.) being sufficient to control a very heavy infection. Owing to its slow excretion atebrin appears to exert a more prolonged action than quinine but there is more chance of relapse with the drug.

The treatment of chronic intestinal amœbiasis presents many difficulties in the tropics and none of the treatments recommended in this condition may be considered satisfactory. Chemotherapeutic studies were, therefore, conducted both in the laboratory as well as in hospital with the alkaloids of the *Kurchi* bark (*Holarrhena antidysenterica*) and an organic arsenic derivative called carbarsone. *Kurchi* is a well known remedy of the indigenous medicine in India and it was exhaustively investigated at the School both chemically and pharmacologically. An extensive trial was given to both the individual alkaloids contained in the bark and also the total alkaloids. A preparation of the total alkaloids, called 'kurchi' bismuth iodide however, showed a great promise of efficacy and encouraging results were obtained with this preparation. The laboratory experiments and clinical observations so far made with carbarsone appear to give the impression that it is a safe, efficient and reliable remedy for amœbiasis.

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Indian Chemical Society, and The Indian Journal of Agricultural Research. The Proceedings of certain Societies, such as The Physiological Society of India, and the Grant College Medical Society, etc., also contain some of the papers.

PROGRESS OF MEDICAL RESEARCH WORK IN INDIA DURING THE PAST TWENTY-FIVE YEARS.

By

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CONTENTS.

I. INTRODUCTION.

The amount of medical research work carried out in India and the contribution to the knowledge of the various peculiar conditions that affect the health and well-being of the people have not been small during the past twenty-five years.

The problems facing the research workers in Medicine are multifarious, varied and beset with difficulties in India. Yet the spirit and zeal of the medical men in India are ever increasing and a great volume of useful work is now being done in every province.

Only a short account of medical research in India during the period under review will be presented here.

Among the principal diseases which devastate the population of India are malaria, kala-azar, plague, cholera, typhoid fever, dysentery and influenza. The annual toll of human life and suffering attributable to these diseases is alarming. The problems of filariasis, ankylostomiasis and tuberculosis are not any the less important.

Diseases due to malnutrition and to the peculiar socio-economic conditions, which are engaging the attention of the authorities at the present day, are also of special interest to the country. Most of the problems connected with these diseases cannot be remedied unless and until the economic condition of the population is greatly improved and the standards of life, education and hygiene are greatly raised.

In one of his Annual Reports the Public Health Commissioner writing about the control of tuberculosis said that 'In the practice of more hygienic methods of living, in the provision of ample and nutritious food supplies and generally in a wider appreciation of the dangers inherent in harmful social practices will be found the way to a gradual decrease of this scourge of civilization and generally to healthier and happier people'. This is not only true of tuberculosis but also of many of the other important diseases prevalent in this country.

India is a vast country and the problems in the different provinces are not alike. All varieties of temperature and climate are met with in India. Variations from the arctic climate of the Himalayas to the equatorial conditions of scorching heat and high humidity are in existence. The torrential rains of the sub-Himalayan tracts on the east of India are in marked contrast to the absolutely dry climate of Rajputana, Sind, etc. The variations in the diet and habits of the people are also equally marked. The people of different provinces take entirely different diets. From the fairly well-balanced diet of the Punjabee to the ill-balanced diet of the Madrasee and the Bengalee all grades of defective diets are met with. The nature, distribution and importance of diseases, therefore, necessarily vary from province to province. For example, if we draw a line from Simla to Cape Comorin, kala-azar prevails east of this line, and oriental sore west of the line. Plague is confined more to Western India and there is less plague in Eastern India. The malarial problem of the Punjab is different from that of Assam. The distribution of cholera follows the main riverine routes from its home of endemicity in Bengal, though here the quick methods of travel now available have altered the distribution to a great extent.

II. Cholera.

Our knowledge of the bacteriology of the *Vibrio choleræ* has been very limited for a long time past. Greig introduced differentiation of cholera and para-cholera vibrios by means of hæmolytic reactions. Investigations on the differentiation of vibrios by agglutination methods, however, have proved only of limited value for their classification. Reports of many non-agglutinating cholera vibrios found in convalescents and healthy persons acquiring agglutinability after a time and *vice versa* are found in the records of investigations published from time to time. Tomb and others

considered that non-agglutinating vibrios could, under favourable circumstances, be transformed into true agglutinating cholera vibrios. Taylor and Ahuja found that agglutinable vibrios from healthy individuals in an endemic area of Bengal were indistinguishable from true cholera vibrios. They also found that non-agglutinating vibrios isolated from water of a non-endemic area in Kohat—far removed from Bengal—developed all the biological characters of the true cholera vibrios including agglutinability, after six months of subculture.

Linton, Shrivastava and others working on the antigenic structure of cholera and other vibrios found that a study of their chemical composition would be helpful in differentiating the pathogenic from non-pathogenic varieties. Linton's classification of the vibrios on the basis of their chemical structure has been shown to fit in better with the epidemiological findings than serological or biological methods of classification. Linton and co-workers found on an analysis of the carbohydrate fractions of various vibrios that they could be divided into three types, namely (*a*) containing galactose combined with an aldobionic acid, (*b*) containing arabinose combined with the same aldobionic acid, and (*c*) containing only glucose. The vibrios from cholera cases were generally found to fall into group *a* but sometimes into group *b*; the water vibrios fell into group *b* only; the vibrios isolated from carriers or obtained from old laboratory cultures fell into groups *a* and *c*. Thus they found that a mere study of the carbohydrate structure failed to differentiate satisfactorily the various vibrios. A study of the protein fractions, showed the presence of two types of proteins, I and II. On the basis of the discovery of the three types of carbohydrates and of the two types of proteins they divided the vibrios into six groups. According to this grouping vibrios of groups I and II were found to be invariably associated with cholera cases; vibrios of group III were derived from water, vibrios of groups IV and V were carrier strains and vibrios of group VI were old laboratory cultures. They also worked on the problem of dissociation of the vibrios. In this connection a remarkable series of experiments was conducted specially with reference to the gain and loss of specific carbohydrates, appearance of a dissociant of an entirely different type of protein and carbohydrate.

D'Herelle found that bacteriophage played an important rôle not only in the epidemiology of cholera but also in the cure of the disease. He found that persons in whom bacteriophage was feebly developed or not developed at all, usually died of cholera, but those in whom strong bacteriophage was present usually recovered. He prepared active bacteriophage for field trials and reported good results after its use in the Punjab. D'Herelle claimed that natural recovery in cholera was the result of the development of bacteriophage in the bowels. The phage destroyed the cholera vibrios or converted them into harmless non-agglutinating vibrios.

He also claimed that if contaminated wells are treated with bacteriophage they become free from cholera vibrios. Ross corroborated D'Herelle's views and found that active bacteriophage was directly associated with natural recovery from the disease. He, therefore, recommended that phage should be tried extensively in cholera.

D'Herelle and Malone classified choleraphages into Nos. 1 to 10 in proportion to their strength and advocated treatment of cholera with the powerful bacteriophages contained in Nos. 9 and 10. It was found that these phages could rapidly destroy the virulent vibrios in culture. In their opinion, the cessation of epidemics was ascribed to the wide dissemination of bacteriophage throughout the community and in its environment.

The work of D'Herelle in India was continued by Asheshov. He found three types of bacteriophage, A, B and C. While any single member of these three types failed by itself to destroy the whole of a virulent cholera culture, a combination of all three types was effective in destroying all the vibrios. Asheshov and others described the methods of preparation, classification, and determination of virulence of bacteriophages. Row found that within optimum limits, lysis by type A of choleraphage is enhanced by increasing the acidity, and type B by increasing the alkalinity. Pasricha and deMonte described a new type D and later described types E and F of bacteriophage. They suggested classification according to the lysability by pure line choleraphages and stated that B, C and D types undergo mutation in nature.

The prophylactic use of bacteriophages has been tried in different parts of India with varying results. Wells were also treated with bacteriophage. By these measures the incidence of cholera was reduced by 90 per cent as compared with untreated controls. Trials in Bihar gave good results. But the extensive trials carried out in Madras failed to give very promising results.

Regarding the treatment of cholera cases with bacteriophage Morison stated that the bacteriophage treatment of cholera in the Khasia Hills was remarkably successful.

Anti-cholera vaccination originated by Haffkine has had an extensive trial in this country for a number of years and expectations have been well realized. Its merits are appreciated and it is very popular with the public health authorities.

Considerable work has also been done on the epidemiological aspects of cholera. Greig found, from a study of epidemics, that the spread of the disease occurred through pilgrim routes. Brahmachari showed, by statistical analysis, that cholera epidemics occurred periodically every 5 years in most provinces.

Russell and Sundararajan investigated the question of periodicity of cholera incidence in the different provinces of India by means of 'periodogram analysis' and demonstrated a five-yearly cycle in Eastern Bengal and Assam and a six-yearly cycle in other parts of India. They found that while temperature and atmospheric pres-

sure have very little direct correlation, humidity has a fairly high positive correlation and rainfall a negative correlation in certain areas. Rogers after studying records of 60 years for each province of India, declared that it was possible to forecast every serious cholera epidemic by taking into consideration the cholera mortality during the previous three years, the distribution and amount of rainfall during the past year and the movement of absolute humidity to or beyond a critical level as the cholera season approaches.

Ross's work showed that the climatic conditions of temperature and humidity act through favouring the prevalence of flies. Gill and Lal found that the fly was not merely a mechanical carrier of the vibrio and they adduced evidence to suggest that the vibrios undergo a biological transformation in the fly.

The treatment of cholera with intravenous injection of hypertonic saline was introduced by Rogers and constitutes a great advance in the treatment of the disease. It is indicated in the treatment of anuria, regard being had to the conditions of the pulse, blood pressure, specific gravity, alkalinity and *p*H value of the blood of the patient.

III. PLAGUE.

Plague is another dreadful disease that is widely prevalent in India causing an annual mortality of about 100,000 people. The most valuable contribution to our knowledge of plague was made by the Indian Plague Commission. The Commission were the first to show that plague is primarily a disease of rats and that infection spreads from rats to man through the bite of fleas. An epizootic of the disease occurs first among rats, *R. norvegicus* and *R. rattus*, and this epizootic is followed by an epidemic in human beings. Plague in the rats is a septicæmia and the fleas parasitic on them get infected by ingesting their blood. The plague organisms multiply in the gut of the flea and are transmitted to rats and man by the bites of the infected fleas. Although the Commission concluded that rat fleas were responsible for transmission, they did not study the rôle or importance of the different species of fleas in epidemiology of the disease. From the investigations of Rothschild, Hirst, Cragg and others, much information was gathered in this respect. Hirst developed his well-known theory that the distribution of plague was related to the prevalence of certain species of rat fleas. He found that *X. cheopis* had far greater plague-carrying powers than *X. astia* or *X. braziliensis*, and that 'climatic conditions limit but do not govern the geographical distribution of rat fleas.' Webster and Chitre after making a flea survey of Bombay, showed that the prevalence of *X. cheopis* is 5 to 12 times more numerous on *R. rattus* than *X. astia* and that *X. braziliensis* was rare in Bombay. They also found that the

'Blocking phenomenon' with plague bacilli in the fleas resulting from the influence of climatic conditions was a very important factor in the spread of plague; on account of this even with a rather limited range of temperature and humidity during the epidemic season in Bombay a much larger proportion of infected fleas are able to transmit the disease. Goyle confirmed Hirst's theory about the importance of cetain species of fleas as determining factors in the prevalence of plague. He found that *X. cheopis* was a more efficient vector than *X. astia*. He also found that at a temperature of 68° F. transmission by *X. astia* was checked by a saturation deficiency of 0·3 of an inch, while the transmission by *X. cheopis* was only stopped by a saturation deficiency of 0·6 of an inch.

P. J. Barraud found that both *X. cheopis* and *X. astia* were present in Assam, the average number of each per rat being about 9, and yet Assam has been free from plague. It is a puzzle why plague does not flourish in Bengal, Assam and in some other provinces of India. Row made a detailed study of the factors influencing the rise and fall of epidemics of plague in India in general and the causes for the disappearance of the disease from Calcutta in particular. His results show that while conditions favourable for the transmission of infection still exist in Calcutta and other areas, plague has failed to spread in them due to some unknown factor connected with the secular trend characteristic of the disease.

The absence of plague in Madras city has, however, been found to be due to the fact that the *astia* index of Madras is nearly 100 per cent; whereas in infected areas like Bombay it is the *cheopis* index that is very high.

About 40 years ago, the annual plague mortality in India was 1,300,000. This figure has now been reduced to less than 100,000 per year, mainly through improvement in hygiene and sanitation, through a campaign against rats and rat fleas and finally through a wider use of prophylactic vaccination.

An effective method for the destruction of both rats and fleas has been found in the treatment of rat holes with cyano-gas. This is a proprietory preparation, capable of liberating hydrocyanic acid gas when exposed to air. In the Cumbum Valley in the Madras Presidency the value of cyano-gas fumigation in the control of plague has been tested on an extensive scale and found to be excellent. Reports from other parts of India are also very favourable. Thanks are due to the Rockefeller Foundation for financing some of these researches and for helping to popularize cyano-gas in the control of plague.

For immunization of susceptibles, Haffkine's plague vaccine is still used. It has given excellent results in India. An enormous amount of useful work has been done on the preparation and standardization of plague vaccine by Naidu, Jung and others at the Haffkine Institute, Bombay.

Regarding the clinical varieties of plague, besides the bubonic, septicæmic and pneumonic types, a new type called 'cellulo-cutaneous' type has been described by Choksy.

Regarding treatment, no tangible results have so far been obtained. Various antiseptics like iodine, carbolic acid, mercurochrome, and others have been tried. None of the drugs can be said to be satisfactory. Bacteriophage treatment has been found to be useless. The latest line of research work on the treatment of plague is with regard to the preparation of a potent anti-plague serum for therapeutic use. Sokhey has recently evolved quantitative methods for measuring the virulence of strains of *Past. pestis* and the protective value of plague vaccines. Large quantities of specific anti-serum have been prepared at the Haffkine Institute from horses and are awaiting field trials. The preliminary tests, however, show that the use of this anti-plague serum reduces case mortality by over 50 per cent. The results of this important work are being awaited with great interest.

IV. Malaria.

Malaria is the most important and widespread of all the diseases prevalent in India. It causes the greatest amount of morbidity and mortality; over 100 million people suffer from the disease and nearly 1 million die of it every year. Since Ross's monumental work on the mosquito transmission of malaria, workers in India have carried out an enormous amount of valuable research work on various aspects of malaria. The work of James, Christophers, Barraud, Sinton, Puri and Iyenger on the entomological aspect, specially with reference to the identification of Indian species of mosquito adults and larvæ, is extremely valuable. Gill's work on the epidemiology of malaria in the Punjab with special reference to the forecast of epidemics is recognized to be of a high order. The studies of Sinton, Covell, Menon, Krishnan, Bailey and others on the relation of irrigation to malaria in different parts of India have helped greatly to advance our knowledge of the subject. The investigations of Chalam, Senior-White and others on the relation of malaria to Railways and of Strickland on hill malaria are highly enlightening. The observations of Bentley on malaria and bonification in deltaic areas in general and in the Gangetic Delta in particular are well-known. The elucidation of the special features of the Assam malaria problem by Rice and Ramsay has been of enormous practical importance in control work. The demonstration of the value of 'drug prophylaxis' in malaria through mass distribution of quinine in the rural areas of India furnishes some hope for the future of rural malaria control in India. The early and timely discovery of the migration into Bengal of *Anopheles ludlowi* or as it is now known *A. sundaicus* Rod., which was discovered by Brahmachari years ago in Calcutta, and the possible

dangers from it to Calcutta, by Iyengar and Senior-White has considerably helped to check epidemic prevalence of the disease through this agency in Calcutta. The contributions of Knowles and Das Gupta on the parasitology of malaria in man and monkey have clarified many important points. Reference may be made to the cytological and splenectomy experiments of Krishnan and Napier with special reference to the rôle of the spleen and of the reticulo-endothelial system in malarial immunity. Reference may also be made to P. Brahmachari, U. Brahmachari and Banerjea's work on the chemotherapy of quinoline compounds. The discovery of a monkey *Plasmodium* causing hæmoglobinuria has opened up many new lines of investigation, particularly for the testing of new antimalarial drugs. Work in this direction is being conducted by Chopra, Shortt and others and is likely to be of great practical value in chemotherapy. Very recently, Taliaferro and Mulligan have worked out the histopathology of malaria with special reference to the macrophages in defence.

An enormous amount of work has been done on malaria in India particularly by Christophers and Sinton. In the earlier days Christophers collaborated with others, notably with James, Bentley and Liston, and in more recent years, he was in part responsible for advising or directing the researches of malariologists, among whom we may mention Sinton, Barraud, Covell, Shortt, Gill, Puri and others. This school of malariologists has been engaged in such diverse aspects of this problem as malarial surveys, the collection of epidemiological data, field experiments on mosquito reduction, the prevention of malaria in selected urban or rural areas, the forecastings of epidemics, the prophylactic uses of quinine and other antimalarials.

Reference may just be made here to the work on blackwater fever by Christophers and Bentley, malaria research in the Andamans, the Federated Malay States and in the Dutch East Indies by Christophers and malaria in Mesopotamia and antimalarial operations at Busra by Christophers and Shortt. Brahmachari and Sen have noted that during active hæmolysis in blackwater fever, the greatest amount of hæmolysis takes place in the liver. The recent work of Krishnan and co-workers on blackwater fever has thrown light on the ætiology of the disease and the lines of treatment that may profitably be adopted.

V. Kala-Azar.

Kala-azar was, until recently, one of the most terrible of tropical diseases. Although limited in distribution, it is a disease of enormous public health and medical importance in the localities in which it exists. So far as India is concerned, this disease is of particular importance not only because it has sometimes assumed epidemic character and devastated several areas in Bengal

and Assam, but also because the discoveries of the causal agent, the mode of transmission of the disease and the latest advances in the successful treatment of a disease once considered incurable have all been made in this country.

Soon after the discovery of the parasite of kala-azar, *Leishmania donovani*, Rogers succeeded in cultivating the Leishman-Donovan bodies and demonstrated the flagellate forms of the parasite in culture. Row succeeded in inducing experimental leishmaniasis in the monkey and the mouse by the injection of the parasites in culture. In more recent times the morphology and development of the parasites have been worked out exhaustively by Christophers, Shortt and Barraud.

During the last 20 years much attention has been directed in India towards the improvement of the diagnostic methods in kala-azar. The method of diagnosis by spleen and liver puncture is, of course, the best, but its employment is practically restricted to hospitals. Methods have also been devised for flagellate culture from the peripheral or splenic blood in N.N.N. medium. Brahmachari pointed out that there was increased amount of globulin as also the presence of an easily precipitable globulin in the serum of kala-azar patients. His *globulin opacity test* and *globulin ring test* were the earliest methods of serum diagnosis in kala-azar. These as well as the later tests devised by Napier (*aldehyde test*) and by Chopra (*urea-stibamine test*) are probably dependent upon the above-mentioned factors.

With regard to the transmission of kala-azar earlier investigations conducted in India led to the suspicion of the bed bug being the transmitting agent of the disease, but this view has now been discarded. Thanks to the researches conducted at the Calcutta School of Tropical Medicine by Knowles, Napier and Smith and by Christophers, Shortt and Barraud of the Kala-azar Commission in Assam, it is now more or less conclusively proved that the sandfly, *P. argentipes*, is the transmitter of kala-azar in India.

Christophers, Shortt and Barraud have demonstrated the whole cycle of development of Leishman-Donovan bodies in the sandfly *P. argentipes*. They found that the laboratory-bred female *P. argentipes* when fed upon parasite containing blood of kala-azar patients showed herpatomonad forms in their fore- and midgut on the 3rd to the 5th day of the feed. The flies got rapidly fertilised and oviposited on the 4th day and then died. If females were kept separate from males and were made to feed a second time after 4 days then they could be kept alive for 8 days. The infection became very heavy and the whole of their intestinal canal, from the proventriculus to the rectum, became engorged with flagellates. Since these findings numerous attempts were made to infect man by infected flies but with no success. Shortt, Smith, Krishnan and Swaminath, however, succeeded in infecting hamsters (a Chinese rodent susceptible to *L. donovani* infection) through the bite of

infected sandflies. Thus although actual transmission of the disease to man has not yet been accomplished, the transmission of infection to hamsters through the bite of infected *P. argentipes* affords almost conclusive evidence that this insect is probably the vector in kala-azar. The recent discovery in China of *L. donovani* in the throat and the confirmation of the same by Shortt lead to the suspicion that there may be other methods of infection. Knowles, Krishnan and others in explaining the difficulty of transmitting kala-azar to man advanced the view that healthy man is ordinarily resistant to infection and that only under certain conditions of lowered resistance he becomes susceptible to infection with *L. donovani*. This view led to an investigation of the factors responsible for susceptibility and resistance in kala-azar by Krishnan. He found that susceptibility to kala-azar was determined by a condition of heightened reticulo-endothelial response.

Reference may be made to two very important papers on insect flagellates by Shortt: one on *Herpetomonas ctenocephali* describing its reactions to different environments and the other on the "Pathogenicity of Insect Flagellates to Vertebrates with special reference to *Herpetomonas ctenocephali*." Shortt's observation practically demolished the claims of certain well-known workers that many insect flagellates were pathogenic to birds and mammals.

From 1924–31 over 50 papers on kala-azar and allied subjects were published by Shortt and co-workers of the Kala-azar Commission. The most important of these were: 'Note on a Massive Infection of the Pharynx of *Phlebotomus argentipes* with *Herpetomonas donovani*'; 'The Life-history and Morphology of *Herpetomonas donovani* in the sand fly *Phlebotomus argentipes*' (This paper has been described as a classical paper and the account given has never been criticised in any quarter); 'An account of methods employed in feeding and re-feeding the sand fly, *Phlebotomus argentipes*, for the second and third time on Man and Animals'; 'Note on a Massive Infection of the Buccal Cavity of *Phlebotomus argentipes* with *Herpetomonas donovani*'; 'The Occurrence in Nature of *Phlebotomus argentipes* infected with a Flagellate Morphologically identical with *Herpetomonas donovani*'; 'Infection of Hamsters (*Cricetulus griseus*) with *Leishmania donovani* by the oral and conjunctival routes'; '*Leishmania donovani* in human fæces in Indian kala-azar'; and 'Transmission of Indian kala-azar by the Bite of *Phlebotomus argentipes*'.

Other contributions by Shortt on allied subjects include several papers on the blood parasites of reptiles and batrachia especially *Hæmoproteus argentipes*; *Monocystis mackili*, n. sp. parasitic in *Phlebotomus argentipes*; and life-history and morphology of *Trypanosoma phlebotomi*.

Prior to 1913 there was practically no specific treatment for kala-azar. It was a highly fatal disease and 95 per cent of the persons attacked died of it within a period of two or three years.

Shortly after Cristina and Caronia's successful treatment of infantile kala-azar by means of tartar emetic and the introduction of the drug by Rogers for the treatment of Indian kala-azar, Brahmachari synthesized a series of antimonials, notable among which was a pentavalent organic antimonial, which was named urea stibamine, possessing remarkable therapeutic properties. Shortt was the first to give a detailed account of successful treatment with this drug. Other therapeutic antimonials discovered by Brahmachari need not be mentioned here. Napier has used neostibosan in the treatment of the disease. It has been recommended by him for the intensive treatment of the disease. Recently Lee and co-worker in China have observed that of the drugs used by them, urea stibamine was the most potent in the treatment of the disease. Chopra, Gupta and David showed that the amount of precipitate formed by treating solutions of various pentavalent antimony salts with sera of kala-azar patients, was in proportion to the therapeutic value of the drug and they noted that of the many antimony compounds tested by them, urea stibamine yielded the largest amount of precipitate. Brahmachari and Brahmachari have observed that intensive courses in which the injections of urea stibamine are administered daily or on alternate days are effective.

In Assam mass treatment with urea stibamine was initiated by Government and as a result the prevailing epidemic of kala-azar was controlled, and the incidence of kala-azar in Assam has also been greatly reduced. In 1933, the Director of Public Health, Assam, noted that 'it is no exaggeration to say that approximately 3·25 lacs of valuable lives have been saved to the province. Other accruing advantages to the province may also be apparent.'

In 1922, Brahmachari reported the presence of Leishman-Donovan bodies in nodular growths found on the body of a patient who had a long time previously been cured of kala-azar by antimony treatment. This peculiar skin condition was called '*Dermal Leishmanoid.*' This condition is usually found in a certain percentage of treated kala-azar cases about two years after establishment of the cure. The parasites in these cases are very rarely or never present in the spleen, liver or blood but only in the skin lesions. Since this observation a number of different clinical types has been described by various workers from the early depigmented cases to the extreme nodular types. The histopathology of dermal leishmanoid was studied by Shortt as also by P. Brahmachari. Local lesions in the monkey have been produced by intramuscular injection of scrapings from the nodules.

Viable *Leishmania* have been cultured from these skin lesions in test tubes and sandflies. They are, therefore, a source of infection and the conquest of kala-azar cannot be regarded complete unless these lesions are either averted or quickly cured. Generally speaking, they take a prolonged course of antimonial treatment

and some of them, apparently considered incurable, finally yield to continued use of urea stibamine and metallic antimony inunction as noted by Brahmachari and Banerjea. Recently it has been observed that in many cases the lesions disappear spontaneously after several years.

Apart from the fact that dermal leishmanoid may be a possible carrier of kala-azar, it is very necessary that its treatment should be improved so that the sufferer may be saved from the misery of an ugly disfiguration to himself, his friends and relations, as well as the danger of infection to the public with whom he may come in contact.

VI. Epidemic Dropsy.

Much work has been done regarding the clinical manifestations and etiology of epidemic dropsy. The disease was considered by Greig to be a manifestation of avitaminosis in persons taking polished rice which leads to loss of vitamins or some other vital minute constituents of rice. This view, however, has been given up now. Megaw and Bhattacharji suggested that parboiled rice stored under improper damp conditions gave rise to the disease. Megaw found that in any community the disease was frequently proportional to the amount of rice taken by its members. Acton and Chopra discovered a bacillus in infected rice which they thought produced a soluble toxin in the grains which when ingested produced the disease. A study of opacities in rice points to the possibility of the existence of a transmissible plant virus which leads to a later invasion of the damaged grains by soil bacteria. Dutt considered that the disease was a manifestation of intestinal sepsis depending upon the presence of a specific micro-organism. Lal and Roy, as a result of their epidemiological investigations of a few outbreaks in Bengal and Assam and also as a result of laboratory experiments, have recently brought forward evidence in favour of the old mustard oil theory. The theory was first suggested by Mitter (Howrah) from his clinical observations and later on further confirmatory evidence was put forward by Sen (Calcutta). Mustard oil may be contaminated with some impure constituents or there may be present an infective agent or its toxin in some brands of mustard oil which may be responsible for the disease. The disease often occurs in explosive outbreaks, which are generally made up of a number of localized explosions. These leads to the suspicion of an infective material being responsible for the disease. The important views regarding the etiology of the disease may be summarised as: (1) Rice theory, (2) Mustard oil theory, and (3) Infections-contagion theory. None of the above theories alone can, however, explain all facts in connection with the disease. It is possible that more than one factor is concerned in the etiology and it is evident that further work must be done in this direction. The view that the disease is different from the wet form of beri-beri

is not yet completely proven. In some cases the occurrence of the disease fits in with the consumption of one brand of rice while in others with the consumption of some brand of mustard oil.

Shanks and De have published detailed studies on the pathology of the disease. R. N. Chopra and U. P. Basu have found tincture of ephedra to be a useful remedy in the treatment of the cardiac complications of the disease.

VII. Filariasis.

Filariasis is a very wide-spread disease in India and according to Megaw and Gupta it occurs all along the sea-coast and in the Gangetic valley. Although it does not directly contribute towards an increase of mortality, there can be little doubt that it does cause an enormous amount of sickness and suffering in the affected areas. Isolated workers in different parts of India, like Cruikshank and Wright in Cochin, Cruikshank, Cunningham, Seethapathy and Pandit, and Pandit and Iyer in Madras, Das in Puri, Korke in Bihar and Orissa, Sundar Rao in several parts of India and Iyengar in Travancore, have carried out interesting research work and made very valuable contributions to our knowledge of filariasis. Iyengar has shown that two types of infection are concerned in the causation of filariasis in India, namely *Wuchereria bancrofti* and *Filaria malayi*, the former infection being common in the urban and the latter in the rural areas. Certain differences have also been observed with regard to the clinical manifestations caused by the two infections ; while genital affections are extremely rare in areas where *F. malayi* is prevalent, they are quite frequent in *W. bancrofti* areas. The exact distribution of the two types of filarial infections has not yet been determined. A knowledge of it would be very valuable in control work, as *W. bancrofti* is transmitted by *Culex fatigans*, while *F. malayi* is transmitted by mosquitoes of the genus *Mansonioides*. The methods of control for the two species of mosquitoes are quite different. The young stages of *Mansonioides* stay below the water surface and are unaffected by treatment with larvicides. They can be controlled only by certain biological methods, such as the removal of those types of water plants that favour their breeding, as has been suggested by Iyengar from studies in Travancore.

As regards the treatment of filariasis, considerable research has been carried out in India, but we have yet to find a drug that would kill the microfilariæ, or check an attack of lymphangitis.

Acton and Rao carried out extensive researches on the respective rôles of filariæ and of pyogenic organisms in the causation of lymphangitis. Their conclusions were that the worms merely damaged the lymphatics and rendered them susceptible to bacterial infection and that the actual cause of the attack of lymphangitis

was bacterial invasion, the source of the bacteria being some septic focus or foci in the body.

VIII. Leprosy.

In India it is estimated that there are over 150,000 cases of leprosy. Many workers all over India are devoting their time to the study of the problems connected with the disease and they have within the last twenty-five years made many valuable contributions to our knowledge of the disease. The names of Rogers, Muir, Lowe and others are well known in this connection.

All attempts to grow Hansen's bacillus by culture *in vitro* have so far been unsuccessful. In India Muir, Henderson, Lowe, and others have attempted to grow the organism in various special media, including a tissue culture medium, but the results have so far been negative.

The mode of transmission of leprosy is not definitely known. Muir, Lowe and others, from a study of the problem in a large number of cases, considered that in all probability the disease was transmitted through contact with infectious cases. But even so, the exact mode of entry of the organism into the body is not known.

As regards the incubation period of leprosy, Rogers, as a result of his studies, came to the conclusion that on an average it is over 2 years and 2 months.

Muir, Lowe, Chatterji and others have developed various useful laboratory techniques for the detection of *Lepra bacilli* in nasal scrapings, gland-puncture material, scrapings of skin and pieces of nerves from anæsthetic cases. They have also studied the sedimentation rate, fragility of red blood cells and blood cholesterol content in leprosy with a view to determine their value in diagnosis and prognosis. Muir and Lowe have conducted extensive epidemiological studies on leprosy in India and have brought out many points of interest as regards age and sex distribution, predisposing factors and mode of spread of infection. They have not only shown that the highest incidence of leprosy is in the middle age period but also that in the majority of instances infection is probably contracted in childhood which is the period of maximum susceptibility. They state that children from birth to 6 years of age are the most susceptible; between the ages of 11 and 25 only debilitated persons contract the disease in a severe form and the healthy persons of that age-group generally escape or at worst develop non-infective types of the disease. With regard to sex incidence they found that males suffer from the disease more than females, in the proportion of 2 : 1, and suggested that endocrine deficiency may be responsible for this variation. With regard to the degree of spread of infection in a locality they found that it could be determined by a study of the length and closeness of contact, the degree of infectiousness of the cases and

the resisting powers of the persons exposed to infection. With regard to resistance to leprosy they established that a good diet, specially one containing plenty of milk increases resistance and prevents infection ; they also found that the wide prevalence of the infection was invariably associated with a low economic state.

It is well known that for a long time the treatment of leprosy had been very unsatisfactory. In India the Ayurvedic physicians of old used chaulmoogra oil in the treatment of the disease. They generally administered the oil by mouth. This oil is a nasty drug causing great discomfort and lepers were loath to take the oil. In 1916 the oil was tried by injection in the Philippines, but it led to painful swelling and severe reaction, and had to be given up. It was left to Rogers in India to prepare a soluble sodium salt of the fatty acid of the oil and use it by intramuscular and intravenous injections with great benefit. In his method of treatment there was no discomfort and improvement was rapid. Rogers and Ganguli also obtained good results from the use of sodium morrhuate. Muir tried ethyl esters of chaulmoogra, olive, linseed, cod liver, gurjan and neem oils, and found that esters of hydnocarpus oil were of the highest therapeutic value. Formerly hydnocarpus oil was expensive because it was obtained only from *Taractogenus Kurzie*, which grows only in the dense jungles of Burma. Muir found that this oil could also be obtained from *Hydnocarpus Wightiana* which grows abundantly in certain parts of Southern India. The oil of this plant was found to be as efficacious in leprosy as the oil from *Taractogenus Kurzie*, and by this discovery Muir was able to reduce very greatly the cost of treatment of leprosy. Lately Muir advocated routine treatment with *Hydnocarpus Wightiana* oil with 4% creosote in increasing doses from 4 to 10 c.c. intramuscularly ; when full doses failed to excite local reactions, he advocated sodium hydnocarpate intravenously. A large number of other adjuncts to treatment have also been worked out by Muir and co-workers, and leprosy today is not the hopelessly incurable disease that it was years ago.

An important contribution of Muir in the case of leprosy is his demonstration of the fact that leprosy is, in the majority of instances, a curable disease. By successfully treating several thousands of cases he has shown that early cases of leprosy can be cured and infective cases can be rendered non-infective through appropriate treatment. He is confident that leprosy can be stamped out from India provided (i) enough dispensaries are opened for the detection and treatment of cases, (ii) enough medical men could be trained to undertake this special work, and (iii) sufficient funds could be found for carrying out the above scheme. It is gratifying to note that many local bodies have already adopted Muir's recommendations and are deriving the benefits predicted by him. Rogers has made another valuable contribution to leprosy. He has been responsible primarily for the establishment of the British Empire

Leprosy Relief Association. He conceived the brilliant idea of starting a central organisation for the relief of leprosy for the whole of the British Empire and sent out an appeal for funds. The response came from every corner of the Empire with the result that this vast humanitarian organisation came into existence in 1928 and commenced its useful work soon after. In India a good part of the leprosy work that is being done today is financed by this Association. With such an organisation in existence it only remains for us to hope that the patience, perseverence and industry of the many selfless workers all over the world will help to stamp out this much abhorred disease.

IX. Dysentery.

The most momentous advance in the treatment of amoebiasis in recent times was the introduction by Rogers of the injection of emetine hydrochloride, though the oral administration of the drug had previously been advocated by Tull Walsh and its toxic action on the amoebæ studied by Vedder. Administered intramuscularly, it was shown by Rogers to be effective in amoebic dysentery, in pre-suppurative hepatitis and amoebic abscess of the liver. The introduction of the drug has reduced the occurrence of amoebic abscess of the liver and the death rate from the disease to a remarkable degree. Acton and Chopra have shown the efficacy of the active principles of *kurchi* bark in the treatment of dysentery. *En passant* it may be mentioned that *kurchi* is well known in indigenous medicine for centuries as a specific for the disease.

The works of Cunningham in Bengal jails, of Krishnan in Cannanore jail and of Theodore in Bellary jail on the method of detection and treatment of latent dysentery of bacterial origin which form the bulk of the most dangerous carriers of infection and which constitute the chief source of the disease, have greatly helped in the control and prevention of the infection in jails. Through the adoption of the measures recommended by these workers the incidence of dysentery in the jails in India has been greatly reduced. Bacteriophage was also used by Morison with good results in Assam in the treatment of dysentery.

X. Typhus Fever; Relapsing Fever; Sand-fly Fever and Dengue; Cerebro-spinal Fever.

Typhus Fever

Megaw described tick typhus of India in 1916. It is a fever resembling louse, mite and flea typhus but differing from them in that it is conveyed to man from the rodents by the bite of ticks, and occurs chiefly among the Europeans while out shooting and fishing in the hills or open country but rarely amongst children of the indigenous popula-

tion. The best known infected localities are Bhim Tal and Sat Tal at an altitude of 4,500 feet in the Kumaon Himalayas.

Cragg lost his life in India from typhus fever during his investigations of louse-borne typhus through accidental infection contracted in the laboratory. Typhus fever though having only a very limited distribution in India, occurring chiefly in the North West Frontier province, is of particular importance to the army stationed there. The work of Cragg, Megaw and Shortt has shown that in India more than one form of typhus occurs. The prevalence of louse typhus and tick typhus has been established by Megaw and Cragg beyond any doubt. The work of Shortt suggested that flea typhus also may be present in India. He has worked out the distribution of tick typhus in India and made important laboratory findings in the disease. In Kasauli wild rats caught in nature have been shown to harbour the virus in their brain and transmission of the virus has been shown to occur in these animals through fleas. U. P. Basu reported cases of exanthematic typhus in Calcutta occurring amongst children with their clinical symptoms.

Relapsing Fever

Mackie showed that the body louse was the important vector of the disease in India. In the Punjab, and probably in other parts of India, epidemics occurred in 1869, 1878, 1891, 1906 and 1920 (Gill). Cragg observed that in the United Provinces of Northern India though the disease was usually most prevalent in the winter months, localized outbreaks of the disease occurred in the hot season in April and May but declined in June. The early hot weather is very favourable to the rapid development of the carrier lice, and the later very hot months are equally unfavourable. He also fonnd that the epidemic of 1917 in the United Provinces, as well as other outbreaks, including the great famine fever in Bombay in 1877, were related to maximum temperatures in May of 10°F. or so below normal favouring the continued activity of the lice—a relationship that should enable future epidemics to be foreseen by watching the meteorological records. Gill has described outbreaks in the Punjab, where Cragg found the conditions favouring the disease similar to those of the adjacent United Provinces, and he has recorded experiments proving that many more lice survived when the temperature was comparatively low and the humidity high in the critical month of May. Russell has reported outbreaks of relapsing fever from August, 1922, and May, 1923, in Madras.

Sachs concluded from clinical evidence that both tick and louse-borne relapsing fevers occurred in Chitral. Cunningham, and subsequently Cunningham and co-workers have shown that spirochætes of relapses in relapsing fever differed serologically from the spirochætes present in the first attack. They have isolated 9 serological types of spirochætes showing no morphological differences. Experiments to determine the origin of the various types

gave the conception of an organism composed not so much of pre-existing antigenic elements as of potential variants. The change of type seems to be a gradual process and occurs at different times during the disease. Occasionally infections with more than one type of spirochæte have been observed.

Sandfly Fever and Dengue Fever

In 1906 McCarrison described the 'Three Days' Fever of Chitral', and emphasized its resemblance to dengue, except for the absence of the secondary rise of temperature and rash. He also suspected sandflies of being the vectors. The 'Seven Day Fever' described by Rogers and the 'Five Day Fever' by the present writer were cases of dengue. The observations of Knowles in Calcutta, and the careful investigations of Chandler and Rice on dengue in America, led them to exclude spirochætes as the cause of the disease. Shortt was the first to cultivate the viruses of dengue and sandfly fevers on the chorio-allantoic membrane of the chick-embryo.

Cerebro-spinal Fever

The following notes are made from Russell's paper presented at F.E.A.T.M. congress at Nanking:—Cerebro-spinal meningitis is no new disease in India, it has appeared in epidemic form in certain parts of India in recent times, notably in Calcutta, Delhi and Ahmedabad city of Bombay Presidency. There seems to be a tendency for epidemics to die out with increasing day temperatures. Attempts have recently been made to prepare anti-meningococcus serum at the Central Research Institute, Kasauli, Haffkine Institute, Bombay, and other places. The strains of meningococcus isolated from Delhi and other places have been so far found to be of type III (Group I), whilst they react with the Oxford sera to full titre as though they were the same strains as the English ones.

XI. Rabies; Snake-venoms and Anti-venenes.

Rabies

Semple in 1912 introduced his method of preparation of the rabies vaccine, which consists of a carbolised suspension of fixed virus contained in the brain and spinal cord of infected rabbits. This vaccine has now been shown to be very efficacious and is being manufactured and used in most Pasteur Institutes even outside India. Speaking for India it has greatly helped in the distribution of vaccine to different mofussil centres and making treatment easily available for all. Cunningham studied the value of etherised vaccines. In 1934 Shortt made a valuable investigation into the relative immunising value of Kasauli and Paris strains of rabies fixed-virus. This may be said to have established the basis for the present methods of anti-rabic inoculation in use in India. His morphological studies on rabies include study of the salivary glands and the negri bodies in the hippocampus major in street virus

infections. Ayengar has studied the nature of the electric charge possessed by rabies-virus.

Snake-venoms and Anti-venenes

Acton and Knowles observed that the antibodies in antivenene were in combination with serum globulin and could be precipitated from the immune goat's serum by 40% saturation with ammonium sulphate, while Moitra and co-workers noted that with the sodium-sulphate method at least a three-fold concentration of antivenomous serum could be obtained. Venkatachlam and co-worker found that sub-lethal doses of the venom of the Indian cobra paralyse the motor end-plates, while with bigger doses animals die long before this takes place. Chopra and Chowhan have observed that the paralytic action of the venom of Indian Daboia on the capillaries resembled that of histamine shock. Chopra and co-workers found that the venom of *Echis carinata* had a marked curara-like action on nerve endings and death was primarily due to circulatory failure analogous to that in histamine shock. They, as also Ganguly, Ganguly and co-worker have studied the biochemical properties of Indian snake-venoms. Taylor and Mallick have studied the action of rattle-snake and Mocassin venoms as compared with Indian viper venoms.

XII. Tuberculosis; Rheumatism and Heart Disease.

Tuberculosis

The subject of tuberculosis as an important public health problem in India only attracted attention towards the latter part of the first decade of this century. Joshi, Liston, Soparker, Taylor and Ukil have demonstrated that the bovine tubercle bacillus, which plays an important rôle in the causation of pulmonary and non-pulmonary tuberculosis in Europe, hardly takes part in the causation of human tuberculosis in this country, partly because tuberculosis amongst cattle is comparatively rare and partly because the people invariably boil the milk they drink. The distribution of tuberculosis in India, which is chiefly a rural country and which is now on the threshold of industrialization, presents a peculiar and complex problem brought about by the constant mingling of the virgin rural population with the comparatively small population of highly tuberculized urban and industrial areas. The epidemiology and pathology of the disease and the part played by solar radiation in influencing tuberculous infection in the tropics have been studied, in recent years, by Ukil. He has shown that exudative changes are more marked features of the disease here than in Europe, particularly in rural and semi-rural areas. Chatterji has noted that the death-rate of Hindu women from tuberculosis in the Delhi Province was higher than that of Mohamedan women. He ascribes this to the defective protein dietary of the Hindus. In the domain of clinical medicine, Frimodt-Moller, Benjamin, Kesava

Pai, Ukil and others have added to the stock of our knowledge of tuberculosis in this country. Kesava Pai and co-worker have studied the value of the suspension stability of red corpuscles in determining the prognosis of pulmonary tuberculosis.

Good deal of propaganda work in connection with tuberculosis has been taken up in India in recent years by the Tuberculosis Association, thanks to the aid of the King George V thanksgiving fund and the various Indian Red Cross Societies, though much more intensive work is undoubtedly necessary in this direction.

Rheumatism and Heart Disease

Up to recent times the view has been held by European observers that rheumatism did not occur among Indians. Rogers noted that of 4,000 post-mortem examinations in Calcutta, only one showed rheumatic carditis. But in the experience of Indian practitioners, true rheumatism and rheumatic endocarditis are not at all uncommon, though their observations have not been recorded. In more recent times Vere-Hodge, U. P. Basu, Hughes and Yusuff, Stott and others have noted rheumatic heart lesions among Indians. It may be noted here that more than 80 years ago Chevers quoted from Webb's 'Pathologia Indica' that diseases of the circulatory system were very common in India. He regarded carditis as a prominent feature in the general pathology of the country, and would appear to infer that acute inflammation of the heart might be even more prevalent in India than it was in Europe. In recent times U. P. Basu and Acton have gone so far as to note that about 50% of the so-called healthy Bengalees showed myocardosis. Hughes and Yusuff have observed the presence of the degenerative type of non-syphilitic heart disease among Indians, probably of rheumatic origin. The conclusion is that true rheumatism and rheumatic carditis occur among the Indians, though they are not so common as in England. It is significant that chorea and rheumatic nodules are rare among Indian children as compared with those in England as noted by Vere-Hodge.

XIII. Diseases of Nutrition.

'In a country like India where a large proportion of the population exists in a condition of chronic economic stress, it is not to be wondered at that diseases due to defects in nutrition are widespread'. This formed the basis for extensive and valuable investigations in the nutritional diseases of India by McCarrison, and only recently questions relating to diet and nutrition have began to attract attention in India. There are two principal centres at present where studies on the subject are being pursued, one at Calcutta and other at Coonoor. The work taken up at both these centres may be divided broadly as follows: (i) The investigation

of the nutritive value of the Indian foodstuffs, and (ii) the study of the composition of Indian dietaries, their relation to health and deficiency disease.

Studies on the composition of Indian diets are yet few and the ground surveyed is not very large. They provide sufficient proof of the existence of under- and malnutrition in this country. The food supply of many areas in India falls short of the proper requirements. Just, by way of example, mention might be made of the diet of a group of village families surveyed by Dr. Aykroyd and his colleagues. This consisted of protein 30·00, fat 5·00, carbohydrates 369·00, calcium 0·69, phosphorus 0·75, and calories 1660 ; fruits and vegetables were altogether absent from the diet ; meat, eggs, and milk were negligible. The quantity of rice was insufficient. The inadequacy of such a diet is obvious. Another diet survey of the middle class families of Calcutta undertaken by Wilson, Ahmad, and co-workers did not reveal general quantitative deficiency, but the diet was found to be poor in total and animal protein, total and animal fat, calcium, and contained too little of dairy products with an excess of cereals. These two surveys represent more or less the diets of the poor and middle class families in most parts of India.

Nutrition surveys among school children in Calcutta and the Punjab have shown a wide prevalence of dental defects including caries, etc. In Calcutta the incidence of caries varies from 22–56% among the different communities while in the Punjab the incidence was 30–38%. There was a high incidence of enlarged tonsils and the average height and weight of the poorer children were markedly below those of the children of better classes. Nutrition surveys carried out by Aykroyd and his colleagues in Southern India have also shown the wide prevalence of the symptoms of deficiency disease. In one survey covering a group of 1,900 children, 6·4% showed phrynoderma (toad skin), 9·2% angular stomatitis (sore mouth), and 3·8% bitôt spots. All these conditions are attributable to deficiencies of the diet. Evidence of a high incidence of keratomalacia and xerophthalmia resulting from vitamin A deficiency in Southern India has also been obtained. A large percentage of the blindness is the direct consequence of these conditions. Wright at one time described 76 cases of xerophthalmia in Madras among children under five, two-thirds of whom became ultimately blind.

In the Northern parts of India rickets and osteomalacia occur ; in certain districts the incidence is very high. Cataract as well as urinary and renal calculi occur in the Punjab, and there is a certain amount of evidence that the occurrence of these conditions might be related to the diet. The work of McCarrison has shown that vitamin deficiency may produce a defective keratinization of the genito-urinary tract and give rise to stone in the bladder, a small focus of infection forming the nucleus.

Wilson and co-workers have shown in the human subject that the volume of urine is less and the oxalate and phosphate excretion greater on an *atta* (wheat) diet such as is consumed in the Punjab than on the rice diet of Bengal. Considerable work on various fractions of vitamin B has been done by McCarrison, Guha, Sankaram, De, Krishnan and others. Orr has made valuable contribution on the investigation of etiology and pathology of peptic ulcer in South India. It appears that it is due to the excess of carbohydrate diet, deficiency of protein and a general vitamin deficiency, in which vitamin A appears to be the most important.

There is evidence to show that changes may take place in the vegetative nervous system due to defective diet and McCarrison showed that spastic condition of the gastro-intestinal tract was common in animals fed on autoclaved carbohydrate diets. He also demonstrated changes in the Auerbach's plexus in experimental animals.

These are just a very few facts about the occurrence of the grosser types of deficiency disease in India. Nutrition research has been seriously undertaken only recently, and the finer symptoms of partial deficiency have scarcely been studied. The problem is of the gravest importance and it is the most fruitful line along which public health work should develop in this country. Fortunately the Indian Research Fund Association has taken up the matter, and it is hoped that as more funds become available, researches in this very important field will help in ameliorating the condition of the poorer classes of India.

XIV. Indian Indigenous Drugs Enquiry.

In addition to the earlier enquiries on the subject, the Indian Research Fund Association has been financing research in this direction in recent times, principally under the control of Chopra, and many drugs of the indigenous system of medicine have been investigated. As an example, mention may be made of the study of the active principles and therapeutic properties of the roots of *Rauwolfia Serpentina*, which were originally reported on by Brahmachari in the monthly-meeting of Asiatic Society of Bengal in March 1912, and in more detail in recent times by Chopra and co-workers. The drug possesses marked hypnotic properties. Its active principles have also been studied by Chopra as well as by Siddique and co-workers. Some work on indigenous medicine is being carried on by Greval.

The problem of drug addiction in India has been studied by Chopra.

XV. Medical Research Associations and Institutions and Research Workers.

Among the various bodies concerned with medical research in India which have been established within the last twenty-five

years or a little earlier, the most important is the Indian Research Fund Association. The importance and value of the work done by the Association and published in the Indian Journal of Medical Research and its Memoirs, the records of Malaria Survey of India and in the Reports of the Scientific Advisory Board demonstrate the need for the encouragement of the activities of the Association.

The Indian Research Fund Association employs a number of research workers, finances enquiries, makes grants to cover expenses of researches carried out by Government research officers and others and, in every possible way encourages the prosecution of medical research in India. Its activities cover a very wide field, and have enormously added to the scope and extent of work carried out.

The Research Institutes in Medicine in India to-day include the Central Research Institute, Kasauli; Pasteur Institute of India, Kasauli; King Edward VII Memorial Pasteur Institute and Medical Research Institute, Shillong; The Calcutta School of Tropical Medicine; All-India Institute of Hygiene and Public Health, Calcutta; The King Institute of Preventive Medicine, Guindy; The Pasteur Institute of Southern India, Coonoor; The Haffkine Institute, Bombay; The Vaccine Institute, Belgaum; Central Provinces Vaccine Institute, Nagpur; The Punjab Vaccine Institute; Provincial Hygiene Institute, Lucknow; Government Bovine Lymph Depot, Patwadangar. A part of the research work in these institutions is financed by the Indian Research Fund Association, and one of them, namely, the Central Research Institute, Kasauli, may be regarded as its chief laboratory.

Among the recent trust funds in Medicine in India, the most important is the Lady Tata Fund created by the munificence of Sir Dorab Tata in the memory of his wife. The smaller trust funds include the Mitra Endowment for Research in Diabetes in the Calcutta School of Tropical Medicine and the Parlakemedi Endowment held by the Indian Research Fund Association. The Calcutta School of Tropical Medicine holds many other endowments which need not be detailed here.

It is a notable fact that in the Universities there are very few endowments for research in Medicine. Speaking of the University of Calcutta where large sums of money have been endowed by the munificence of Sir Tarak Nath Palit and Sir Rash Behary Ghose, etc., for research in basic sciences, like Physics and Chemistry and chairs created for the same, very little facilities are available for medical research. The smaller research funds include Maharajah of Durbhanga and Kalyan Mukerjea research funds.

India needs institutions like the National Institute for Medical Research. The Rockefeller Foundation has extended its generosity to India by creating fellowships for Indian scholars, by initiating

research in India in diseases like ankylostomiasis, etc., and by helping in the foundation of the All-India Institute of Hygiene and Public Health. May the Indian princes, commercial magnates and owners of hoarded wealth in India, aided by the Imperial and Provincial governments, come forward for the creation of a federal institution for medical research in India.

Some years ago, Lord Rutherford, at an Annual Meeting of the Royal Society of Medicine, referred to the application to Medicine of scientific methods and the growth of the ancillary sciences, namely, physiology, bacteriology, and biochemistry. He remarked 'I foresee the time, not far ahead, when more funds and more help will be available to extend in a multitude of directions that scientific work which lies at the basis of your profession, and which is necessary if you are to gain any serious understanding of the human body. You have made great advances, but I am sure that all of you here know how little has been done, and how much remains. I feel confident that in the future every country in the civilized world will join in an international attack on the problem of the diseases that afflict mankind'. In this the League of Nations should be able to participate to a great extent. The above remarks are specially applicable to tropical diseases.

This Chapter may be concluded with an expression of the hope that one day India will see the creation of Chairs of Clinical Research with Clinical Research Hospitals, under the auspices of the universities and medical research associations; that before long there will be in India full co-operation between the official and non-official research workers in Medicine; that proper facilities will be given for research in medical schools and colleges, whether official or non-official; that the independent medical profession will be allowed to work in research institutions, whether state-owned or otherwise; and that the researches in Medicine conducted in different parts of India will all be pooled together for annual discussion in the Section of Medical Research of the Indian Science Congress or some other organized body; and finally that ample funds will be placed at the disposal of the Indian universities and medical schools and colleges for medical research.

XVI. Bibliography.

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PROGRESS OF PHYSICS IN INDIA DURING THE PAST TWENTY-FIVE YEARS.

By

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Contents.

I. Introduction.

The development of the physical science in India has not, like that of other sciences, a long history.[1] During the last century,

[1] The author wishes to acknowledge his indebtedness to Dr. K. Ramnathan, whose article 'On India's Contribution to Modern Physics' in the Sri Ram Krishna Centenary Volume has been of great help in the compilation of the present Report. Dr. Ramnathan has also looked through the proofs in their final form.

the only work worth mentioning was done by individual scholars in various Scientific Departments of the Government. Such, for instance, were the investigations on Terrestrial Magnetism by Alan Broun at Trivandrum and by Chambers and Moos at Colaba. The foundations of Indian Meteorology were laid by H. F. Blanford in 1867. The work of the Trigonometric Survey of India, which was founded in 1818, though not connected with physics directly, led to a fundamental discovery in Geophysics, viz., that of Isostasy. It was based on Gravity-anomalies observed in the Himalayan region by Capt. Basevi and others, and these results on being shown to Archdeacon Pratt of Calcutta, who was a qualified mathematician, led him to invent the theory of isostatic compensation. It is known that this theory has exerted great influence on the progress of Geophysics in the present century. In 1845, Radhanath Sikdar, the head computer of the Trigonometric Survey and an accomplished mathematician, found from mathematical reduction of the observations made some years earlier on an obscure-looking peak of the Himalayas, that this was actually the highest peak in the world (since known as Mount Everest, after Col. Everest the retired Surveyor-General during whose regime the observations were made).

From the Indian point of view, however, the first contribution to physics to receive attention in Europe was made by the late Sir Jagadish Chandra Bose who, while a subordinate professor at the Presidency College, Calcutta, took up the study of Hertzian waves in 1895. He carried out a number of remarkable investigations on the generation of ultra short electric waves having a wavelength of the order of a few mms., and studied their properties. With an ingenious instrument of his own device [*Vide Ency. Britannica* (11th Edition), Vol. 9, p. 206] he verified the laws of reflection, refraction, polarization and double-refraction, and clearly demonstrated the rotation of the plane of polarization for Hertzian waves. By making use of spiral springs, he invented a new type of coherer which was very efficient. Considering the extremely meagre facilities which were at the disposal of Indian scientists at the time, Prof. Bose's contributions must be regarded as unique, and his researches received well-merited recognition from British and foreign scientists. Unfortunately these investigations were not continued, as Sir Jagadish's attention was diverted to other channels.

These works, as also the work of Prof. D. N. Mallik and A. K. Das at the Presidency College, Calcutta, on electric discharge in the de la Rive tube were isolated.

The first great impetus towards organized study of the physical science was given by the establishment of the University College of Science at 92, Upper Circular Road, Calcutta, out of endowments given by two Calcutta lawyers, Sir Tarak Nath Palit and Sir Rash Behari Ghose. These endowments were due to the far-sighted vision, and untiring energy of Sir Ashutosh Mookerjee, who controlled the policy of the Calcutta University from 1904–1924, and

than whom a greater benefactor of Education in India has yet to be born. It is remarkable that almost all the names at present prominent in Physics in India, viz., C. V. Raman, D. M. Bose, S. K. Mitra, S. N. Bose (of Bose-Einstein Statistics fame), M. N. Saha, P. N. Ghosh, B. B. Ray, are or were at some epoch of their life, connected with this institution. Mention should also be made of the Indian Association for the Cultivation of Science, 210, Bowbazar Street, Calcutta, which was founded in 1876 by a Calcutta medical man, Dr. Mahendra Lal Sircar, with the object of providing facilities for the teaching of, and for carrying out researches in science. This action was taken nearly sixty years ago, at a time when the Government and the public were equally indifferent to science. The Association was founded mostly out of private benefactions, to the amount of seven lakhs of rupees raised by prominent citizens of Calcutta and a donation of fifty thousand rupees by the Maharaja of Vizianagram. In 1922, the Government of India granted a subsidy of Rs.18,000 per year to the Association. The Association was converted into an important centre for researches in Physics in 1915 by Sir (then Mr.) C. V. Raman, who was then an officer in the Finance Department of the Government of India. In 1930, the Association received a further donation of over a lakh of rupees from Rai B. Beharilal Mitra, a wealthy citizen of Calcutta, with which a Professorship in Physics, called the Mahendralal Sircar Professorship was founded.

Since the educational reforms of 1921, active centres of research have been created in other cities of India, the most noteworthy financial contribution being that of the Maharajah of Jeypore (Madras) towards the founding of the College of Science at the Andhra University, Waltair. Other donations which have helped in the cultivation of physical science are the endowment given by the late Kumar Guruprasad Singh of Khaira to the Calcutta University, the endowments of various princes of India to the Universities of Aligarh and Benares, and the endowments by the citizens of Bombay for the Royal College of Science, Bombay.

Though the necessity of introducing regular courses of university study in Applied Physics [1] had been recognized for a long time and was urged by the Industrial Commission of 1917, and the Sadler Commission, no action on the recommendations was taken anywhere in India either by the Government or the Universities till the late Sir Rash Behari Ghose donated a sum of Rupees eleven lakhs and forty-three thousand for founding a department of applied physics in the Calcutta University. This donation was not, however, supplemented by a response from the Government, and regular teaching could be started only in 1930.

[1] For information on this section, the author is indebted to Prof. P. N. Ghosh to whom grateful thanks are due.

At present amongst the Indian Universities only Calcutta has a department of Applied Physics under Prof. P. N. Ghosh. This laboratory is divided into:

(*a*) A standardization section containing arrangements for standardization of all kinds of electrical meters, and photometers;
(*b*) A machine section containing all types of motors, generators and transformers;
(*c*) A design section; and
(*d*) An electrical communication section.

The last two are designed for preliminary training only.

The other industrial research laboratories which may be mentioned in this connection are:

(1) The *Research Laboratory* of the *Central Cotton Research Committee* at *Matunga, Bombay* (Director: Dr. Nazir Ahmed); where researches on the strength of fibres, constitution, etc. . . . are carried out.
(2) The *Government Test House* at *Alipore*, which confines itself to testing of materials, and calibration of instruments on a limited scale.

Prof. H. Parameshwaran at the Presidency College, Madras, has made considerable studies on the making of Clocks and Telescopes in India.

In the preparation of this review, the editor has received very material help from the following gentlemen, who as a matter of fact are the actual writers of the articles put against their names:

I.	Introduction, by the Author	
II.	Acoustics	Dr. R. N. Ghosh, Reader, Allahabad University.
		Dr. M. Ghosh, Burdwan Raj College, Bengal.
III.	Applied Physics	Prof. P. N. Ghosh, Ghosh Professor of Applied Physics, Calcutta University.
IV.	Astrophysics	Dr. D. S. Kothari, Head, Department of Physics, Delhi University.
V.	Chemical Physics	Dr. P. K. Sen Gupta, Rajaram College, Kolhapur.
		Dr. H. K. Trivedi, Government Test House, Alipore.
		Dr. L. S. Mathur, Meteorological Service of India.
VI.	Magnetism	Dr. D. P. Ray Chowdhury, Scottish Churches' College, Calcutta.
VII.	Optics and Raman-Effect.	Dr. S. C. Sircar, University College of Science, Calcutta.

VIII.	Radio-activity, Positive Rays.	Dr. D. M. Bose, Palit Professor of Physics, Calcutta University.
IX.	Spectroscopy ..	Dr. K. Majumdar, Allahabad University.
		Dr. S. C. Deb, Indian Association for Cultivation of Science.
X.	Theoretical Physics.	Dr. R. C. Majumdar, Bose Research Institute, Calcutta.
XI.	Wireless Research .	Dr. G. R. Toshniwal, Allahabad University.
XII.	X-rays ..	Prof. B. B. Ray, Khaira Professor of Physics, Calcutta University.
XIII.	Meteorology	Dr. A. K. Das, Meteorologist, Solar Observatory, Kodaikonal.

To all of them his grateful thanks are tendered.

II. Acoustics.

Theory of Bowed Strings

The history of acoustical researches in India dates back to the year 1912 when Sir C. V. Raman[1] (then Mr.) published the results of his experiments on the subject, in *Physical Review*, under the title 'Some Remarkable Cases of Resonance'. These experiments became the starting point for further researches on the vibration of strings: (i) in a periodic magnetic field, and (ii) when the initial vibrations are set up by discontinuous wave motion. Raman, in collaboration with A. T. Dey[2] applied these results to explain the 'Wolf Note' phenomenon in bowed strings with the aid of the theory of discontinuous wave motion given by Hermann, Davis and others, and later on wrote a complete memoir on the theory of bowed strings for the *Handbuch der Physik* series comprising about 160 pages and numerous plates.

It may be noted in this connection that K. C. Kar[3] first showed experimentally that the position of the 'Zeropoint' having the same velocity as the bow is generally within the bowed region. B. N. Biswas has given a dynamical theory of the bowed string, the formula deduced being the same as that of Helmholtz excepting the damping factor.

Vibration in Air due to impinging spheres

Investigations on the vibrations generated by impact were carried out in the laboratory of the Indian Association by S. K. Banerji[4] who studied the distribution of the intensity of sound in air round the sound field of the colliding balls,

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1 C. V. Raman, *Phys. Rev.*, **35**, 449, 1912.

2 C. V. Raman and A. T. Dey, *Proc. Ind. Assn.* (Cal.), **2**, 1, 1916; **2**, 41, 1916; **2**, 26, 1916.
C. V. Raman, *Bull. Ind. Assn.*, **15**, 1918.

3 K. C. Kar, *Phys. Rev.*, **21**, 695, 1928.

4 S. K. Banerji, *Phil. Mag.*, **32**, 96, 1916.

both experimentally and theoretically. He devised a ballistic phonoscope with which he carried out the measurements. This work was further extended by D. B. Deodhar[1] (Lucknow).

M. Ghosh and his co-worker S. C. Dhar[2] developed a general theory of the longitudinal vibrations excited by the impact of an elastic load. This theory was able to explain the dependence of duration of contact on the velocity of the hammer and the wave produced in the bar as observed by Tschudi and others.

Percussion Instruments

Indigenous musical instruments, *Tabla* and *Mridanga* possess an air chamber closed on one side or both by a membranous covering similar to Kettledrum. The difference is that the central region of these instruments is loaded with a thick layer of hard paste. These instruments, unlike the Kettledrum and other European membrane instruments produce musical notes rich in harmonics. The instruments are loaded and damped in such a manner that all the overtones over the 9th harmonic are suppressed. This and the determination of the position of nodal lines have been experimentally studied by Raman[3]. An attempt has also been made by R. N. Ghosh[4] to explain the behaviour of the loaded membrane.

Impact of Pianoforte Strings

The investigation on the impact of pianoforte strings was started some time late in the year 1918 in the laboratory of the University College of Science, Calcutta. C. V. Raman and B. N. Banerjee[5] studied the duration of impact of a hard hammer when the striking point was shifted along the string. The object was to test Kaufmann's theory. It was found, however, that Kaufmann's theory holds good only for small values of striking distances. A new theory applicable to all points was developed by considering that the motion that ensues is the resultant of inharmonic vibrations of the string having a load of mass m (hammer mass) at the point of impact. Later K. C. Kar[6] pointed out that it is not correct to take Rayleigh's solution in the form of a series, as done by Raman and Banerjee. This objection of Kar has been confirmed by the later works of K. C. Kar and M. Ghosh[7], but the objection was met by a paper 'On the validity of Raman and Banerjee analysis of the Pianoforte string' by K. Venkatchala Iyengar[8].

[1] D. B. Deodhar, *Phil. Mag.*, **48**, 90, 1924.
[2] M. Ghosh and S. C. Dhar, *Ind. Phys. Math. J.*, **3**, 15, 1932 ; **3**, 73, 1932.
[3] C. V. Raman, *Proc. Ind. Acad. Sci.*, A, **1**, 179, 1934.
[4] R. N. Ghosh, *Phil. Mag.*, **45**, 315, 1923.
[5] C. V. Raman and B. Banerji, *Proc. Roy. Soc.*, **97**, 49, 1930.
[6] K. C. Kar, *Phil. Mag.*, **6**, 276, 1928.
[7] K. C. Kar and M. Ghosh, *Phil. Mag.*, **9**, 306, 1930 ; *Zeits. f. Physik*, **61**, 525, 1930 ; **66**, 414, 1930.
[8] M. Ghosh, *Ind. Journ. Phys.*, **7**, 365, 1932. See, however, K. Venkatchala Iyengar, *Proc. Ind. Acad. Sci., Bangalore*, **1**, 61, 1934.

The above investigations related to hard hammer ; the problem of elastic hammer for small values of striking distances was undertaken in the laboratories of the Allahabad University, and a damped harmonic law of force was obtained by Messrs. S. R. Bhargava and R. N. Ghosh [1]. This law of force imparts to the string the requisite amount of energy when the hammer rebounds. Experiments were made by Mr. J. N. Dey [2] and others to test the formula. K. C. Kar [3] made some improvements on the Raman and Banerjee's theory, and with M. Ghosh extended the same to the case of a damped string. M. Ghosh later developed a generalized theory on the basis of the previous one including Hertz's theory of impact, and has shown that the theories given by Kaufmann, Helmholtz, Delemer, Lamb, R. N. Ghosh, and P. Das [4] come as special cases. Recently R. N. Ghosh [5] has applied Heaviside operational method to solve the pianoforte problem, both in the form obtained by late Mr. P. Das and also in the form obtained by Raman and Banerjee. This applies both to elastic and hard hammers for all striking distances.

On the experimental side, systematic study of the duration of contact was made by M. Ghosh, D. Banerjee and R. Ganguli [6], R. N. Ghosh [7] and S. Dhar, S. K. Datta [8], K. C. Kar and S. C. Laha [9]. R. Ganguli studied experimentally the different harmonics present in the vibrations of a struck string. D. Bose studied the effect of finite breadth of hammer upon the duration of contact. R. N. Ghosh [10] studied experimentally the intensity of air-borne sound of a piano when the striking distance was varied over the string. L. D. Mahajan [11] obtained beautiful vibration curves of the sound board and traced the effect of the damper on the same.

Maintenance of vibration by Heat

D. Banerjee [12] studied the beating notes of the singing flame by taking a large number of photographs of the vibrating flames. B. N. Chuckerbutti [13] and R. N. Ghosh [14] studied the vibration of heated Trevelyan's Rocker.

[1] S. Bhargava and R. N. Ghosh, *Phil. Mag.*, **47**, 1141, 1924.
[2] R. N. Ghosh and J. N. Dey, *Ind. Assn. Culti. of Science Proc.*, **9**, 193, 1925.
[3] K. C. Kar, *Ind. Journ. Phys.*, **7**, 365, 1932.
[4] P. Das, *Ind. Assn. for Culti. of Sci. Proc.*, **9**, 297, 1926 ; **10**, 75, 1926.
[5] R. N. Ghosh, *Acoustical Soc. of America J.*, **7**, 27, 1935.
[6] D. Banerji and R. Ganguli, *Phil. Mag.*, **7**, 345, 1929.
[7] R. N. Ghosh, *Phys. Rev.*, **28**, 131, 1927.
[8] S. K. Dutta, *Proc. Ind. Assn.*, **8**, 108, 1923.
[9] K. C. Kar, R. Ganguli, and S. C. Laha, *Phil. Mag.*, **5**, 547, 1928.
[10] R. N. Ghosh, *Ind. Journ. Phys.*, **2**, 29, 1927.
[11] L. D. Mahajan, *Ind. Journ. Phys.*, **4**, 515, 1930.
[12] D. Banerjee, *Ind. Assn. for Cultivation of Sci. Proc.*, **7**, 47, 1921.
[13] B. N. Chukerbutti, *Proc. Ind. Assn.*, **6**, 143, 1921.
[14] R. N. Ghosh, S. Bhargava, *Phy. Rev.*, **22**, 517, 1923.

Art of Finger Playing on the strings of the Vina

D. Banerjee and R. Ganguli[1] studied the technique of 'Abataran Ash', an art of finger-playing on the strings of the musical instrument, *Vina*, by mechanical means of suddenly increasing the length of the vibration of the string. D. B. Deodhar[2] drew attention to the peculiarities of the Indian stringed instrument.

Clarionet and Harmonium Reed

Late Mr. P. Das[3] developed theories of clarionet, and the maintained vibration of the harmonium reed and explained several facts previously observed by others.

In the subject of ultrasonics, work is in progress in the laboratory of the Indian Institute of Science, Bangalore, under the guidance of C. V. Raman. The line of work is the same as that of Debye in Germany and Sears in America. This work has been considerably extended both along theoretical and experimental lines by Raman and his co-workers, particularly Nagendranath. S. Parthasarthy and P. Ram Pisharothy[4] studied the visibility and dispersion of ultrasonic waves and also determined the acoustical velocity in different organic liquids.

Sound Control

Investigations for finding out a suitable board made out of indigenous material for use as covering material for walls of halls and auditoriums to improve their acoustical properties are of great industrial value. Work in this direction has been started in the laboratory of the Physics Department of the Allahabad University and a considerable amount of preliminary work has already been done. It is found, for instance, that temporary sound control can easily be effected by covering the ceiling and the walls with red 'Toon' cloth. The sound control properties of felt, asbestos sheet and 'thick embossed metal sheet' (painted and unpainted) and other Indian materials have been investigated[5]. Haji Ghulam Mohammed has performed experiments on absorption coefficients which indicate their variation with *intensity*. This result is full of theoretical interest.

Velocity of Sound

A considerable amount of work to determine accurately the velocity of sound in air saturated with water vapour at various temperatures has been done by Haji Ghulam Mohammed[6] by the resonating tube method. The accuracy of the results is claimed to be of the order of about 1 in 1,000 up to the temperature about 60°C., and about 5 parts in 1,000

[1] D. Banerjee and R. Ganguli, *Phil. Mag.*, **9**, 88, 1930.
[2] D. B. Deodhar, *Phys. Soc. Proc.*, **36**, 379, 1924.
[3] P. Das, *Ind. Jour. Phys.*, **6**, 225, 1931.
[4] C. V. Raman and N. S. Nagendra Nath, *Proc. Ind. Acad. of Science*, **2**, 406, 1935 ; **3**, 75, 1936 ; **3**, 119, 1936 ; **3**, 459, 1936.
[5] R. N. Ghosh and H. G. Mohammed, *Ind. Jour. Phys.*, **9**, 167, 1934. Also S. Kalyanram, *Ind. Jour. Phys.*, **2**, 229, 1932.
[6] H. G. Mohammed, *Bull. Acad. Science, U.P.*, **3**, 289, 1934.

for temperatures above this. From these velocity determinations he also calculated the values of the specific heat ratios for moisture.

III. Applied Physics

The research department of the University College of Science under Prof. P. N. Ghosh is provided with arrangements for making precision measurements of dielectric properties of liquids and gases, for studying the properties of Indian oils, and for spectroscopic studies.

A large amount of work on the Electric Moment of Primary Alcohols, and other organic compounds—Ethylene Chloride, and Bromide, Methylene Chloride and Bromide, and their binary mixtures in Benzene, CS_2 and N_2O, some normal secondary and isoalcohols, of alkali monohalides were carried out by P. N. Ghosh, P. C. Mahanti [1] and their co-workers. Indian vegetable oils were studied by G. N. Bhattacharyya and others. S. P. Chakravarti [2] and his co-workers have carried out investigations on electric wave filters and negative resistance equalizers for telephone transmission system. The spectroscopic work is reported separately.

IV. Astrophysics

The first astrophysical work of any importance in India was by the French Astronomer Jansen who, in 1868, observed a total solar eclipse of the sun passing over Guntur, in the Madras Presidency, and applied the spectroscope to the sun during the moments of totality. He found a line close to and on the violet side of the yellow line of sodium. This line was also observed independently by Lockyer, and christened by him 'Helium'. It is now a matter of common knowledge that Helium was discovered thirty years later (1898) by Ramsay in the Norwegian mineral Clevite.

The total solar eclipse of 1898 which passed over Buxar and the Western Presidency was observed by Lockyer, Evershed, and Naegamvela. Photographs of the flash spectra were obtained by all the three observers. Evershed, who succeeded to the directorship of Kodaikanal Laboratory in 1911, instituted a programme for the photography of prominences and systematic investigation of the spectra of sunspots and their penumbra. These observations led him to the discovery of radial motion in sunspots, and simultaneously with Fowler, Hale, Mitchell, and Adams, he reached the conclusion that the spectra of spots was similar to that of the

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[1] P. C. Mahanti, *Zeits. f. Physik*, **94**, 220, 1935; *Phil. Mag.*, **20**, 275, 1935.

[2] G. N. Bhattacharya, *Ind. Jour. Phys.*, **9**, 209, 281, 403, 1936.

K-class of stars. C. Nagaraja Aiyar[1] at Kodaikanal obtained reversal of the D_3-line of Helium in the penumbra of spots. Evershed proved that all spark lines are weakened in the spot; a fact which has been cleared up by the ionization theory. The tradition so happily created by Evershed at Kodaikanal has been continued by his successors, T. Royds (Assistant Director, 1911; Director, 1923–1937), and A. L. Narayan (Assistant Director, 1928, Director, 1937). Evershed and Royds[2] found that many Fraunhofer lines were systematically shifted towards the red, and they were further able to show that these shifts were not due to Döppler Effect, or anomalous dispersion. Part of the shift can be explained as the Einstein red shift; but this does not explain all the observed facts satisfactorily. In recent years, Royds[3] has found that the oxygen triplet 7711, 7772, 7775 can be photographed as a high level chromospheric line even without a total solar eclipse. The intensity and the high level reached by this subordinate group indicates that oxygen is a normal, and very abundant constituent of the solar atmosphere. T. Royds and A. L. Narayan[4] published a photometric study of the lines of H and Ca in the Fraunhofer spectrum at different points on the sun's disc.

The Theory of Thermal Ionization and Radiation

Prof. M. N. Saha's researches[5] on Astrophysics date from the year 1919, whilst he was a lecturer in Physics at the University College of Science, Calcutta. The stimulus for this work was derived from a study of Miss Agnes Clarke's popular books on Astrophysics. Bohr had in 1914 initiated the quantum theory of atomic spectra and Saha, a self-taught physicist, was one of the first in India to take up the study of this theory and perceive its great future. His first papers on the subject '*On Ionization in the Solar Chromosphere*' and '*Elements in the Sun*' were written in India and published in the *Philosophical Magazine, London* (1920), after they were refused publication by some famous astronomical journals. Lockyer had observed that the spectrum of the chromosphere was not an exact reversal of the Fraunhofer Spectrum, but as a rule, the enhanced lines are much stronger in the chromosphere. In fact, it was more like the reversal of the spectrum of α-Cygni (Supergiant Ao). He postulated that in fact the chromosphere had a higher temperature than the photosphere. In his first paper, Saha deduced the famous '*Ionization Formula*' and was able to show that the enhancement of the chromospheric spectrum was due

[1] C. Nagaraja Aiyar, *Astrophys. Jour.*, **26**, 143, 1907.
[2] Evershed and Royds, *Kodaikanal Obs. Bull.*, **15**.
[3] T. Royds, *Nature*, **137**, 610, 1936.
[4] T. Royds and A. L. Narayan, *Kodaikanal Obs. Bull.*, **109**, 375.
[5] M. N. Saha, *Phil. Mag.*, **40**, 472, 1920; **40**, 809, 1920. *Proc. Roy. Soc.*, **99**, 135, 1921.

to a lowering of pressure in the chromosphere. In the second paper (Elements in the Sun), he gave a general explanation as to why only lines of certain elements are observed in the sun. He showed that certain elements like Rb and Cs are completely ionized, while others fail to be stimulated on account of their high ionization and resonance potentials, and due to their most important lines being situated either in the remote ultra-violet or in the furthest red or infra-red. In the paper '*On a Physical Theory of Stellar Spectra*' which was completed at the Imperial College of Science, London, in Prof. A. Fowler's Laboratory, he gave an explanation, in terms of the ionization theory, of the ordered sequence of the Spectra of Stars, which Lockyer had previously tried to explain from a theory of evolution of elements. In the fourth paper '*On the Temperature Radiation of Gases*' he showed that King's work on furnace spectra can be explained as an effect of thermal excitation of elements.

The influence of Saha's work on the subsequent progress of Astrophysics has been admitted by all workers in the field. Prof. Rosseland says 'The impetus given to Astrophysics by Saha's work can scarcely be overestimated, as nearly all later progress in this field has been influenced by it and much of the subsequent work has the character of refinements of Saha's theory'. In the *Ency. Britannica* (14th edition) Sir Arthur Eddington designates Saha's Theory as one of the ten outstanding discoveries in Astronomy and Astrophysics since the discovery of the telescope, in 1608, by Galileo.

It may be mentioned in passing that Prof. Saha [1] is also the originator of the theory of 'Selective Radiation Pressure', which, owing to its publication in 1919 in a *Calcutta Journal* (Journal of the Department of Science, Calcutta University, 1919), had little publicity outside. In this paper, he showed that the formation of the chromosphere and the high level attained by Calcium in the chromosphere can be explained by the action of radiation pressure acting selectively on certain atoms. It is well-known that in the hands of E. A. Milne, and others, this theory underwent great developments and led to the formulation of the first satisfactory theory of Stellar Atmosphere. R. K. Sur [2] working under Saha was able to give a general explanation of eruptive prominences on the basis of selective Radiation Pressure.

S. Chandrasekhar's [3] works on Astrophysics were started in India in 1928, though he has subsequently spent most of his time in England and America. For stellar atmosphere, he has, in an important series of papers, given calculations of the opacity coefficients by using the latest wave-mechanical formulæ for absorp-

[1] M. N. Saha, *Jour. Dept. Sci. Cal. Univ.*, 1919; *Nature*, **107**, 488, 1921.
[2] R. K. Sur, *Astrophys. Jour.*, **63**, 111, 1926.
[3] S. Chandrasekhar, *Ind. Jour. Phys.*, **3**, 241, 1928; *Proc. Roy. Soc.*, **133**, 241, 1931; *Ibid.*, **135**, 472, 1932.

tion coefficients. The new opacity formulæ were used by him in a series of papers for calculating the distribution of temperature and pressure in the stellar photospheres. Following Milne's theory of the Calcium photosphere, Chandrasekhar [1] has given a novel theory of the formation of the chromosphere by considering the field of radiation not to be uniform, but broken up into patches having slightly more than the average and of slightly less than the average value of the intensity (Turbulence). These patches, according to Chandrasekhar, can be identified with the granulations which appear on the solar disc.

Interior of Stars

With this brief survey of the contribution made to the study of the stellar atmosphere by Indian Astrophysicists, we may now pass on to their contributions dealing with the interior of stars. It is well-known that the classical kinetic theory of gases cannot be applied to electrons when their concentration is very large, as it is bound to be in stellar interiors, and particularly in the case of white dwarf stars which are characterized by a small luminosity, high effective temperature and abnormally large densities of the order of a million times that of water. It was shown almost simultaneously by Fermi and Dirac (1926) that the pressure of the degenerate electron gas depends primarily on the electron concentration and is very nearly independent of the temperature. This new formula of Fermi-Dirac was immediately applied by Fowler for explaining the abnormally large mean density of a white dwarf star. This was followed by contributions from numerous investigators including Stoner and Chandrasekhar, and particularly Milne whose work has been of great significance and wide application.

It is now well established that the essential features of the internal constitution of the white dwarf stars can be explained by an application of Fermi-Dirac statistics. In preliminary theoretcial investigations it is usual to regard the luminosity of the white dwarf stars to be zero, that is, to regard it as black dwarf—a term due to Fowler. That the radius of the star calculated on this assumption, which is found to depend inversely as the cube-root of its mass, will not in all probability be modified seriously when account is taken of its small luminosity was shown by Kothari [2]. For finding out the effect of luminosity on the radius of the white dwarf star, it is necessary to know the *opacity coefficient of degenerate matter*. This knowledge of the opacity coefficient of degenerate matter is also essential in all calculations regarding the internal temperature of these stars, and for other astrophysical problems. The opacity coefficient of degenerate matter was first obtained in an important paper by R. C. Majumdar [3] and also by Chandra-

[1] S. Chandrasekhar, *M.N.R.A.S.*, **94**, 13, 1933.
[2] D. S. Kothari, *M.N.R.A.S.*, **93**, 61, 1932.
[3] R. C. Majumdar, *Astro. Nach.*, **243**, 6, 1931.

sekhar [1], and D. S. Kothari [2]. The latter, has further, by an application of the electromagnetic theory, calculated the opacity coefficient in terms of the electric conductivity of degenerate matter. Further it was shown by Kothari that the energy flow in degenerate matter is primarily by thermal conduction and not by radiation as is the case in non-degenerate matter. The calculation of thermal conductivity and other transport phenomena were carried out by D. S. Kothari [3] and later by R. C. Majumdar [4], following a rigorously quantum-mechanical treatment.

We have mentioned above that the pressure of a degenerate gas depends primarily on electron concentration. As the pressure of the gas will be equal to the average kinetic energy per unit volume (multiplied by a factor of the order of unity), the average kinetic energy per electron will depend on the electron concentration and when this electron concentration exceeds about 10^{31} per $cm.^3$ the average kinetic energy per electron becomes greater than its rest mass energy. One has, therefore, to take account of the relativity effect and the corrected formula connecting pressure and electron concentration was given by Stoner, Majumdar and Chandrasekhar [5], who has, in a very elegant manner, applied this exact equation to the study of the constitution of the white dwarf stars and has obtained results of great significance.

But in all the investigations of the white dwarf stars it was tacitly assumed that the stellar material was fully ionized, whereas in a complete treatment, this fact, if true, should emerge from the theory. In degenerate matter the temperature concept is relegated to the background, and the Saha Ionization Formula, so fundamental for non-degenerate matter, loses its validity. The degree of ionization of degenerate matter has therefore to be calculated on other lines. The theory of ionization in degenerate matter has been worked out by R. C. Majumdar and D. S. Kothari [6]. When *cold* and initially un-ionized matter is so compressed (its density increased) that orbits of the outermost electrons of different atoms begin to overlap; then these outermost electrons cannot be regarded as belonging to individual atoms; they are no longer bound to their own atoms but wander, as if it were, in a 'no-atom's-land' and therefore constitute free electrons. The quantitative development of the theory has led to some important results, for example, it predicts that the stellar material in the interior of the white dwarf stars must be fully ionized. It thus connects the theory of

[1] S. Chandrasekhar, *Proc. Roy. Soc.*, **133**, 241, 1931.
[2] D. S. Kothari, *M.N.R.A.S.*, **93**, 61, 1932.
[3] D. S. Kothari, *Phil. Mag.*, **13**, 361, 1932.
[4] R. C. Majumdar, *Zeits. f. Physik.*, **91**, 706, 1934.
[5] S. Chandrasekhar, *Astrophys. Jour.*, **74**, 81, 1931.
[6] R. C. Majumdar and D. S. Kothari, *Zeits. f. Phys.*, **61**, 712, 1930; *Astro. Nach.*, **244**, 65, 1931.

planetary constitution, and in a straight-forward way leads to the interesting result that there cannot be a planet bigger than Jupiter.

This brief summary would, however, be incomplete without a mention of the important work by Chandrasekhar[1] on 'Rotating polytropes', the work of K. Mitra[2], jointly with MacCrea, on solar limb effect, the investigation of R. C. Majumdar[3] on the opacity of relativistic degenerate gas, and of Kothari[4] on the equilibrium between radiation and matter taking account of degeneracy. Recently important contributions have been made by Shiveshwarkar[5] in stellar dynamics.

Problems of Relativistic Cosmogony

The problems particularly studied by the Indian investigators relate to the questions of the expansion of the Universe by condensation of diffuse matter into nebulæ, and the stability of cosmological models. N. R. Sen[6] showed that if the matter of the homogeneous Einstein Universe were packed into homogeneous spherical condensations, a state of equilibrium would be consistent with a slightly greater total mass than was existent in the Einstein Universe. As this slight deficit in mass (apart from any other different cause), whose presence would have just maintained equilibrium would be responsible for the expansion of the system, it was suggested that the expansion of the Einstein Universe could have been started by the condensation of the diffuse matter into nebulæ. N. K. Chatterjee[7] later confirmed that the results remain unchanged if non-homogeneous condensations of mass take place in the Einstein Universe. An attempt to estimate the age of expansion was made by N. R. Sen[8] from the proper motions of the distant nebulæ. If the deviation from the (linear) velocity distance relation be mainly due to the proper motions of the nebulæ, an upper limit to the age of expansion can be estimated from the discrepancy between the observed redshift velocity and the velocity calculable from the distance according to the linear law. An examination of the present data gives the period as being of the order of 10^9 years. N. R. Sen later[9] considered the stability of cosmological models and confirming Tolman's results showed that when the pressure effect is negligible these models are unstable under all conditions, and further, that the consideration of pressure may, in general, alter the situation as in certain cases the pressure may have a stabilizing effect.

1 S. Chandrasekhar, *M.N.R.A.S.*, **93**, 390, 1933 and other papers.
2 K. Mitra, Observatory, **57**, 379, 1934; *Ibid.*, **59**, 160, 1936.
3 R. C. Majumdar, *Astro. Nach.*, **244**, 56, 1931.
4 D. S. Kothari, *Phil. Mag.*, **12**, 657, 1931.
5 Shiveshwarkar, *M.N.R.A.S.*, **96**, 749, 1936; **96**, 758, 1936.
6 N. R. Sen, *Proc. Roy. Soc.*, **140**, 269, 1933.
7 N. K. Chatterjee, *Calcutta Math. Soc. Bull.*, **25**, 135, 1933.
8 N. R. Sen, *Calcutta Math. Soc. Bull.*, **27**, 101, 1935.
9 N. R. Sen, *Zeits. f. Astrophysik*, **10**, 291, 1935.

V. V. Narlikar[1] has obtained from the scalar relation corresponding to the field equations (including λ term) a criterion for the existence of a mass particle, and showed that the breaking up of the Einstein Universe into one with discrete material condensations would mean the increase of the cosmological constant by a factor 3/2. As most of the cosmical matter appears as condensations, it was suggested that λ in the Einstein state has a tendency to increase, which again is mathematically equivalent to the tendency of the static universe to expand.

S. M. Sulaiman[2], applying Newtonian principles, has derived the same law of gravitation as Einstein's for the motion of heavenly bodies. Applying this to light-particles, he showed that the deflection of a light-ray due to the sun's gravitational field is between $\frac{1}{3}$ to $\frac{3}{2}$ times Einstein's value, while the shift of lines to the red is $(1+\sin^2\alpha)$ times Einstein's value, where 'α' is the angle between the line of sight, and the radius vector to the point on the sun's disc, on which observation is made.

The new formula for red shift tallies fairly well with the results obtained by Evershed (1931), and expressed by him in the form of a curve. It yields double the Einstein's value at the edge $\left(\alpha = \frac{\pi}{2}\right)$, as found by Evershed (1936).

Work of Indian Astronomical Observatories

India has only two astronomical observatories: (i) the Nizamiah Observatory, Hyderabad, Deccan (Director: T. Bhaskaran Sastri), and the Solar Observatory, Kodaikanal (Director: A. L. Narayan).

The *Nizamiah Observatory* (founded 1908) is maintained by the Government of H.E.H. the Nizam of Hyderabad and Berar, and is fitted with two equatorial telescopes. The observatory is one of the eighteen which take part in the international photographic mapping of the heavens (*Carte du Ciel*), and has the region between 17°N–23°N assigned to it. Work was started in 1914, and 1,260 areas (each $2'' \times 2''$) were photographed containing 5,21,918 stars down to the 11·5 m. The work was finished in 1928.

The minor planet Eros which is remarkable as sometimes appearing closer to the Earth than Mars, was kept under photographic observation since January 1930, when it had approached to 16 million miles off the Earth. 168 photographs have been taken, and it is expected to calculate from these observations a more accurate value of the solar parallax.

The observatory has also undertaken the astrographic work (+36 to +39) originally assigned to Potsdam, and was given a grant by the International Astronomical Union.

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[1] V. V. Narlikar, *Phil. Mag.*, **14**, 433, 1932.

[2] S. M. Sulaiman, *Proc. Acad. Sci. U.P. India*, **4**, 1, 1934; *Ibid.*, **4**, 217, 1935.

Proper motions of faint stars are observed with the aid of a Blink Photometer (Schlesinger-model).

Occultations of stars, by the moon, and variable stars are observed with a 15″ grubb-refractor.

In 1923, a Milne-Shaw horizontal pendulum spectrograph was erected at the observatory, and a meteorological section was opened in 1929.

The Solar Physics Observatory, Kodaikanal.—The work done at this observatory has already been described. The foundation of this observatory was laid in 1895, by Lord Wenlock, the then Governor of Madras. The buildings and equipments were completed in 1899, and Mr. C. Mitchie Smith was appointed as the first director, when the control was transferred to the meteorological department of the Government of India. Kodaikanal was chosen on account of the suitability of its climate for astronomical observations to take the place of the old Madras observatory.

A good deal of purely spectroscopic work done in this observatory is reported under the heading 'Spectroscopy'. In addition to work reported in the beginning of this section, other works are :—

Hydrogen content of prominences ..	C. P. S. Menon.
Rotation of H_α markings near the equator compared with other disc phenomena.	G. V. Krishnaswami.
General spectrum of the Night Sky ..	K. R. Ramnathan.
Variations in the extent of base and in the height of prominences.	P. R. Chidambar Iyer.
Two longitudinal Zones of apparent inhibition of sunspots on the solar disc.	Do.
Variation in the area of hydrogen absorption marking with longitude.	M. Salaruddin.
A progressive change in the inclination of H_α dark-marking to the meridian of the Sun.	Do.

These papers have been published in the Kodaikanal Bulletins.

V. Chemical Physics and Band Spectra.

Indian workers on chemical Physics have extended Franck's method of interpretation of absorption spectra of alkali halides to other compounds, viz., halides, oxides, sulphides, tellurides and selenides. Franck showed that the absorptions indicated the splitting of the molecule (gaseous) into its constituent atoms, which are either on the normal or excited states.

Alkali Halides

M. S. Desai[1] working at Allahabad verified Franck's theory of photochemical dissociation for Lithium and Rubidium halides. The verification was completed within the limits of experimental error. In the case of RbI the results were rather interesting, because he got more than two absorptions due to the photochemical dissociation of the compound into normal and excited constituent atoms. Desai made further use of Born and Franck's relation to evaluate some of the thermochemical data from the long wavelength limit of the first continuous absorption, e.g., heat of vaporization of Lithium was found to be 29·4 K.Cal. and the heat of dissociation of F_2 unknown at the time, was found to be 76 K.Cal. from the study of the absorption spectra of KF and NaF.

Oxides, Sulphides, etc.

Franck's theory of photodissociation of alkalihalides was extended by P. K. Sen Gupta[2], L. S. Mathur[3] and others to the case of simple diatomic molecules like the oxides and sulphides of Zn, Cd, Hg, Ca, Sr, Ba, etc. These compounds have been shown to be ionic of the type: $M^{++} X^{--}$. It was postulated that the photochemical action on the vapours of these salts resulted in the simultaneous transition of two electrons from X^{--} to M^{++} so that the products of dissociation were usually found to be two neutral normal atoms in the case of the longest wavelength cut, and atoms excited to metastable states in $^1D_2$, $^1S_0$ in the case of cuts on the shorter wavelength side. From a study of the absorption spectrum of HgS, P. K. Sen Gupta found the heat of dissociation of S_2 to be 101 K.Cal. From the study of absorption spectra of the sulphides he also located roughly the position of $^1S_0$ state of sulphur, which was an unknown quantity when the above investigations were taken up.

The extension of the above theory to the case of PbO and PbS was done by R. S. Sharma[4], while compounds CaS, SrS and BaS were investigated by L. S. Mathur on the same lines. H. K. Trivedi[5] studied the absorption spectra of SnO, SnS, FeS, etc. Recently L. S. Mathur[6] has completed the compounds of the oxide group by taking the absorption spectra of the selenides and tellurides of Zn, Cd and Hg.

Higher Oxides and Sulphides

A. K. Dutta[7] and A. K. Dutta and P. K. Sen Gupta showed that saturated oxides like N_2O_5, TeO_3, MoO_3, TeS_3, etc., gave continuous absorptions similar to diatomic compounds mentioned above. Their

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[1] M. S. Desai, *Bull. Acad. Sci., U.P.*, **2**, 31, 1932 ; *Zs. f. Phys.*, **85**, 360, 1933, ; *Proc. R.S.A.*, **138**, 84, 1932.
[2] P. K. Sen Gupta, *Proc. Roy. Soc.*, A, **143**, 439, 1932.
[3] L. S. Mathur, *Proc. Roy. Soc.*, **162** A, 83, 1934.
[4] R. S. Sharma, *Bull. Acad. Sci.*, **3**, 17, 1933.
[5] H. K. Trivedi, *Proc. Nat. Acad. Sci.*, **5**, 34, 1934.
[6] L. S. Mathur, *Ind. Journ. Phys.*, **11**, 177, 1937.
[7] A. K. Dutta, *Proc. Roy. Soc.*, A, **137**, 316, 1932.

absorption spectra were found to consist of two or three regions of continuous absorptions beginning from a long wavelength limit, with intermediate regions of retransmissions. The first absorption was found to correspond to the photo-chemical dissociation in which the oxygen or the sulphur atom was in the normal ^3P-state, while subsequent absorptions were found to be due to the excitation of the oxygen or the sulphur atom to the excited states $^1D_2$ and $^1S_0$. The frequency difference between the long wavelength limits of adjacent absorptions was found to be very nearly equal to atomic term differences $(^3P-{}^1D_2)$ and $(^1D_2-{}^1S_0)$ of the electronegative atom. The cause of slight discrepancy in these differences as obtained from absorption experiments has been ascribed by P. K. Sen Gupta [1] to the varying slopes of the potential energy curves of the unstable excited states of the molecule.

The foregoing absorption experiments afford an interesting possibility of obtaining red auroral lines $\lambda 6363$ and $\lambda 6300$, for a free oxygen atom excited to $^1D_2$ level during the process of photo-dissociation can revert to ^3P-state giving rise to these so-called red auroral lines. A. K. Dutta [2] obtained one of these lines by performing a fluorescence experiment with SO_3 giving a fairly long exposure. P. K. Sen Gupta [3] repeated the same experiment with Nitrous oxide, and obtained bands of NO, which, according to Sen Gupta were produced by photodissociation of N_2O to excited NO and normal N.

Alkaline Earth Halides and Polyhalides

The spectra of alkaline earth halides show both continuous and band absorptions. The compounds CaF_2, $CaCl_2$, $CaBr_2$, etc. were investigated by Deb and Mukerjee [4] and found to give discrete bands in addition to continuous absorption. It was found that in all such cases, the metal component always contained a stable s^2 shell and a metastable orbit.

There was, however, another class of chlorides which were found to give a number of sharp absorption patches with regions of unabsorbed light. This class of compounds include tetrachlorides of Si, Sn, Ti investigated by Dutta and Saha [5], saturated halides of Mg, Al, B, Si, etc. investigated by S. C. Deb and R. S. Sharma [6] and the trihalides of As, Sb, P, Bi, etc. worked by H. K. Trivedi [7]. Dutta and Saha suggested that the frequency limit of the first absorption continuum was approximately given by the relation $h\nu_0 = R/n$ where n is the number of valency bands, and R the

1 P. K. Sen Gupta, *Zs. f. Phys.*, 88, 647, 1934.
2 A. K. Dutta, *Proc. Roy. Soc.*, A, **139**, 397, 1932.
3 P. K. Sen Gupta, *Bull. Acad. Sci.*, **2**, 115, 1933.
4 S. C. Deb, and B. Mukherjee, *Bull. Acad. Sci.*, **1**, 110, 1931.
5 A. K. Dutta and M. N. Saha, *Bull. Acad. Sci.*, **1**, 92, 1931.
6 S. C. Deb and R. S. Sharma, *Bull. Acad. Sci.*, **1**, 92, 1932.
7 H. K. Trivedi, *Proc. Nat. Acad. Sci.*, **5**, 34, 1934.

atomic heat of formation can be linked with other thermo-chemical quantities by the relation

$$R = Q + L_M + \frac{n}{2} D_{x_2} - L_{Mx},$$

where Q is the heat of formation, D_{x_2} heat of Dissociation of the halogen X_2, L_{Mx} the latent heat of vaporization of the compound. For carbon tetra-chloride $R = 466{\cdot}4$ K.Cal where $h\nu_0$ from absorption experiment was obtained as 118 K.Cal, which is approximately one-fourth of R. Other investigators have not in general confirmed the idea of equable distribution of binding energy amongst the different valencies.

Origin of colour of Inorganic Salts

The halides of the elements of the transitional group form a class by themselves. Taking $CrCl_3$ for example, a study of the magnetic moment shows that the structure is of the type $Cr^{+++} . 3\bar{Cl}$. that is, the metal core is ionic and surrounded by $\bar{Cl}^-$ shells of inert gas type. Under photochemical action, the Cl^- ions, being of the inert gas type ($^1S_0$-state), are unaffected, the change occurring only in the spins of the incomplete d^3-shell of Cr^{+++}. M. N. Saha and S. C. Deb [1] tried the experiment and obtained absorption in the predicted region where the spin vector would change under the action of light. Further works on this line have been carried out by S. Kato in Japan, Deutschbein in Germany, D. M. Bose and his pupils in Calcutta.

Simple Organic Compounds

Some of the simplest organic compounds are the Halogen derivatives of Methane, Ethane, etc. P. K. Sen Gupta [2] studied the absorption spectra of a series of organic compounds CH_3Cl, C_2H_5Cl, C_3H_7Cl, etc., while N. K. Saha [3] took the series $CHCl_3$, CH_2Cl_2, CH_3Cl. In the region of quartz spectrograph all these compounds were found to give continuous absorption. It was shown by N. K. Saha that in CH_4Cl_2 there are two absorption processes corresponding to the splitting of a CH and a CCl bond. The difference of bond energies obtained from absorption experiments agreed very well with the chemical values. Recently P. K. Sen Gupta [4] has shown that this difference of bond energies of CH and CCl is not a constant quantity and varies with the number of H or Cl atoms.

Further Developments

In the case of HBr and HI it has been found that the observed beginnings of absorption do not tally with the thermo-chemical value. This difficulty was overcome by A. K. Dutta [5], who showed

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[1] M. N. Saha and S. C. Deb, *Bull. Acad. Sci.*, **1**, 1, 1931.
[2] P. K. Sen Gupta, *Bull. Acad. Sci., U.P.*, **2**, 115, 1933.
[3] N. K. Saha, *Bull. Acad. Sci., U.P.*, **2**, 239, 1933.
[4] P. K. Sen Gupta, *Bombay Univ. Journ.*, **5**, 22, 1936.
[5] A. K. Dutta, *Zs. f. Phys.* **77**, 404, 1932.

that the continuous absorption had such a long tail that to locate the beginning of absorption it was necessary to draw extinction co-efficient—wavelength curves. Each absorption curve of A. K. Dutta was to represent only one process in which Bromine atom was regarded to be in $^2P_{\frac{3}{2}}$ state. P. K. Sen Gupta [1], however, pointed out that A. K. Dutta's absorption curves had a discontinuity, which was due to the superposition of two curves. These two curves apparently represented two processes in which Br atom was in $^2P_{\frac{3}{2}}$ and $^2P_{\frac{1}{2}}$ states respectively.

The theoretical explanation for the type of continuous absorptions without bands, was given by H. K. Trivedi [2] from wave mechanical point of view. He gave an expression for the repulsive potential curve, transitions to which from lower states result in the dissociation of the molecule. He showed that a repulsive potential energy curve, denoting the interaction of two free radicals is represented by an equation of the type

$$U_r = A + De^{-\alpha r}$$

the vibration eigen-values of which are continuous from the dissociation asymptote of the same state. H. K. Trivedi then worked out the most probable values for a Franck-Condon transition from $v'' = 0$ and $v'' = 1$ level of the ground state. From a trial experiment with HBr he obtained the proper constants.

Absorption Spectra and Valency

At the Muslim University, Aligarh, R. Samuel, R. K. Asundi, and their co-workers S. M. Karim, S. L. Hussain, Israrul Haq, Sh. Nawazish Ali, Mumtazuddin and M. Jan Khan have studied the absorption spectra of a large number of polyatomic molecules and complex salts, mostly in solutions. They maintain that the idea that some of the molecules reveal ionic type of binding, as held by certain observers from their experimental data on absorption, is doubtful; and they put forward a theory of p-p coupling to explain the results. A complete summary of their work is given in the Report on 'Absorption spectra and chemical linkage' [3] wherein all the important references will be found.

R. Samuel and his colleagues have recently developed a covalent theory of linking in which they have adopted the electron pair theory with certain modifications and have disregarded the 'one electron bond'. They say that there is only one kind of linking the polarization of which may vary between zero (in H_2) and the value obtained for a true salt. Further it is held that the only

1 P. K. Sen Gupta, *Zs. f. Phys.*, **88**, 647, 1934.

2 H. K. Trivedi, *Proc. Nat. Acad. Sci.*, **4**, 59, 1934; **6**, 18, 1936.

3 R. Samuel, Monograph on Molecular Spectra. *Ind. Acad. Sci., Bangalore.*

type of coupling existing between any two atoms is that between their p-p electrons. They are of opinion that the s^2 electrons act only repulsively.

Band Spectra

P. N. Ghosh and his pupils P. C. Mahanti, B. C. Mukerjee, G. N. Ball, B. D. Chatterjee, A. C. Datta, C. S. Ghosh, A. K. Sen Gupta and M. K. Sen at Calcutta have taken the spectra of MgO, CuO, SnO, CaO, SrO, BiO, BaO, MoO, PO, VO, GaO, GeO, AlBr, PN, AlCl, with a 21 ft. concave grating, and have carried on the vibrational analysis of the bands [1]. P. C. Mahanti has observed the isotope effect in the case of MgO [2]. Investigations on the infra-red spectra of BO and of Bi-carbonates and Marcaptans were carried out by P. N. Ghosh and B. D. Chatterjee, N. K. Sen and A. K. Sen Gupta [3].

R. K. Asundi [4], working at the laboratory of King's College, London, carried out the analysis of the bands of CO. Asundi and Md. Jan Khan [5] carried out the vibrational analysis of SeO, SeO_2. Asundi and Samuel (along with M. Zakiuddin) investigated the band systems of SiF, CdF. Asundi and Samuel gave, from band spectra data, a new value for the heat of dissociation of CO [6]. M. Ishaq [7], working at the Imperial College of Science and Technology, London, studied spin coupling in $^3\Sigma$ levels of *PH* and *PD* and made a rotational analysis of the λ2708 and λ2756 bands of OD.

N. R. Tawde [8] made measurements on the intensity distribution for the violet bands of CN, Swan bands of C_2, and also observed the BF bands in emission. W. M. Vaidya [9] working at the Imperial College of Science, London, and later at the Institute of Science, Bangalore, investigated the flame spectra of CS_2, C_2H_4, and many aromatic compounds.

Active Nitrogen

A general explanation of the active nitrogen phenomena, investigated spectroscopically by A. Fowler and Strutt (Lord Rayleigh II) was given by M. N. Saha and N. K. Sur [10]. They attributed the phenomena to activation of the N_2 molecule to a higher excited state by electrical discharge, and communication of this energy to other atoms or molecules by collisions of the second type. This paper stimulated renewed interest on the subject, and was responsible for a large amount of experimental and theoretical work. P. K. Kichlu [11] showed

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1 P. N. Ghosh and others, see various papers in *Ind. Journ. Phys.*
2 P. Mahanti, *Ind. Journ. Phys.*, **9**, 455, 1935.
3 P. N. Ghosh, etc., *Ind. Journ. Phys.*, **9**, 433, 1935.
4 R. K. Asundi, *Proc. Roy. Soc.*, **124**, 277, 1929.
5 M. Ishaq, *Proc. Roy. Soc.*, A, **156**, 231, 1936.
6 Asundi and Samuel—see various papers in the Indian Academy of Sciences, Bangalore, from 1934–1936.
7 M. Ishaq, *Proc. Roy. Soc.*, A, **159A**, 110, 1937.
8 N. R. Tawde, *Ind. Acad. Sci.*, **2A**, 67, 1935.
9 W. M. Vaidya, *Proc. Roy. Soc.*, A, **147**, 513, 1934.
10 M. N. Saha and N. K. Sur, *Phil. Mag.*, **48**, 421, 1924.
11 P. K. Kichlu, *Ind. Journ. Phys.*, **4**, 111, 1929.

that active nitrogen contained no ionized particles, and was incapable of ionizing sodium. Following his method, the energy of the excited N_2 molecule was fixed at 9·51 volts by European and Japanese workers. Saha and Mathur [1] have shown that in spite of many attempted modifications of Saha and Sur's theory, the original explanation suggested in their paper still holds.

Electron affinity of Halogens

M. N. Saha and A. N. Tandon [2] have developed a general experimental technique for finding out the electron affinity of the halogens by studying the dissociation of alkali halides (like NaCl) into Na^+ and Cl^- in a high temperature vacuum furnace. A. N. Tandon [3] has by this method fixed the electron affinity of I, Br, Cl at 72·6 K.Cal., 80 K.Cal. and 86·6 K.Cal. respectively.

VI. Magnetism.

From a series of measurements on organic substances Pascal has shown that the diamagnetic susceptibility χ of a molecule may be obtained additively from those of the constituent atoms, each linkage introducing a constant deviation depending on its kind. The inorganic compounds show no such regularity of behaviour, but D. P. Ray Chaudhuri [4] showed, on theoretical grounds, that for binary compounds the deviation from additive law will be proportional to the heat of formation of compound, and found it to be generally so.

As the complexity of a molecule increases the distribution of the outer electrons departs more and more from central symmetry and the molecule shows anisotropy in its behaviour. The Cotton-Mouton Effect or magnetic double refraction in a transverse magnetic field has been explained by Langevin on the basis of optical and magnetic anisotropy of the molecules. C. V. Raman and K. S. Krishnan [5] gave an improved theory showing that there exists a quantitative connection amongst data on magnetic birefringence in liquid, those on light scattering and magneto-crystallic behaviour. A large number of measurements on the Cotton-Mouton Effect has been done by Ramanadhan and S. W. Chinchalkar [6]. When optical anisotrophy of a molecule is known from data on light-scattering, the magnetic anisotropy can be calculated from magnetic birefringence. Ramanadhan [7] finds that (i) the two

[1] M. N. Saha and L. S. Mathur, *Proc. Nat. Acad. Sci.*, **6**, 120, 1936.

[2] M. N. Saha and A. N. Tandon, *Proc. Nat. Inst. Sci.*, **3**, 287, 1937.

[3] A. N. Tandon, *Ind. Journ. Phys.*, 11, 99, 207, 1937.

[4] D. P. Ray Chaudhuri, *Phil. Mag.*, **15**, 807, 1933.

[5] C. V. Raman and K. S. Krishnan, *Proc. Roy. Soc.*, **115**, 549, 1927 and **117**, 1, 1927.

[6] M. Ramanadhan, *Ind. Journ. Phys.*, **4**, 15, 1929 ; S. W. Chinchalkar, *Ind. Journ. Phys.*, **6**, 165, 1931.

[7] M. Ramanadhan, *Ind. Journ. Phys.*, **4**, 109, 1929.

anisotropies do not go hand in hand but there are parallel relations in groups of compounds similarly constituted, and (ii) the aliphatic compounds show a feeble negative birefringence while the aromatics show a strong positive one.

This anisotropy of the individual molecules also manifests itself when they are arranged in a regular manner in a crystal. The magnitude of the differences in the susceptibility values in different directions of a crystal will obviously depend on the relative orientation of the molecules within the crystal. Thus these magneto crystallic measurements on diamagnetic crystals are expected to give useful information about the relative orientations of the molecules. Krishnan [1] has devised accurate methods of measurement and studied a number of compounds both organic and inorganic. In many cases it has been possible to supplement X-ray data regarding orientation by means of such measurements.

While the diamagnetic susceptibilities of most substances agree satisfactorily with those calculated theoretically, a few crystalline substances, e.g., graphite, antimony and bismuth show abnormally high values. Ehrenfest and Raman [2] suggested that this is due to the existence of large electronic orbits surrounding many nuclei within the crystal. On this hypothesis pulverization of the above substances will reduce the value of χ. V. I. Vaidyanathan and S. R. Rao [3] show that the above substances in the colloidal state have a low χ value which again decreases with the size of the particle and tends to a constant value. R. N. Mathur [4] claims that a large part if not the whole of this decrease is due to the formation of an oxide layer on colloidization.

The question of orientation of molecules in a magnetic field has been discussed for a long time. If there is any effect it will manifest itself in the viscosity of the substance. S. Chatterjee [5] has studied the change in viscosity of a number of organic compounds in a magnetic field and found that the co-efficient of viscosity changes though this change is very slight.

The name of Prof. S. S. Bhatnagar [6] must be mentioned at this place who with his students did a large amount of work in magneto-chemistry and found interesting relations amongst the χ values of different kinds of isomers. He has also devised a very sensitive magnetic balance for quick determination of χ values, which is now being manufactured by Adam Hilger of London.

[1] K. S. Krishnan, *Phil. Trans.*, **231**, 235, 1933 and later papers in the same journal.

[2] C. V. Raman, *Nature*, **123**, 945, 1929.

[3] V. I. Vaidyanathan, *Ind. Journ. Phys.*, **5**, 559, 1930 ; S. R. Rao, *Ind. Journ. Phys.*, **6**, 241, 1931.

[4] R. N. Mathur, *Ind. Journ. Phys.*, **6**, 181, 1931.

[5] S. Chatterjee, *Ind. Journ. Phys.*, **10**, 399, 1937.

[6] S. S. Bhatnagar in *Physical Principles and Applications of Magneto-chemistry*, by S. S. Bhatnagar and K. N. Mathur. (Messrs. Macmillan & Co.)

Paramagnetism

It is well known that Hund was the first to show how it was possible to calculate the magnetic moments of paramagnetic ions of rare earths and transitional group of elements from a knowledge of the number of electrons present in the incomplete shell and from their quantum numbers. The formula given by him agrees remarkably well with the experimentally determined magnetic moments of the ions of the rare earth group, but fails to explain the magnetic moments of the ions of the first transitional group. Sommerfeld and Laporte tried to improve on Hund's formula by introducing some additional assumptions, without getting much better agreement. D. M. Bose[1] who had been studying the magnetic moments of compounds of paramagnetic elements, gave a rule for calculating the magneton number of such compounds as function of the effective atomic number of the co-ordinating atom. In order to test Bose's rule P. R. Ray and H. G. Bhar[2] prepared and measured the magnetic moments of a large number of complex salts of the iron and other groups, and showed that in certain cases the rule is not obeyed. In order to account for these apparent exceptions Bose[3] gave a theory of the structure of these types of molecules which is an extension of Sidgwick's interpretation of co-ordination bonds, based on the electron theory of valency. From a study of the simple and complex compounds of the iron group, Bose came to the conclusion that in ions of this group of elements the spin moment of the electrons in their incomplete shell alone contribute to their magnetic moments, the orbital moments being quenched. Stoner showed that the quenching of the latter is not complete in all the ions, and gave an interpretation of the mechanism of the quenching based on formulæ given by van Vleck for the moments of the ions of this group. This theory has now been worked out more in detail by van Vleck and his fellow workers.

Since the electrons which are responsible for the magnetic properties of the ions are also responsible for their light absorption, we have a number of magneto optical phenomena. Of these the Faraday effect in solutions containing rare earth ions has been studied by P. K. Pillai[4] and the magnetic birefringence of the same ions by S. W. Chinchalkar[5]. In these two classes of phenomena, the optical properties of paramagnetic compounds are influenced by magnetic fields. D. M. Bose and P. K. Raha[6] discovered a converse effect viz., how the magnetic susceptibility of paramagnetic solutions are influenced by light absorption. The study of these photomagnetic effects has given a new insight

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1 D. M. Bose. *Zeit. für Phys.*, **43**, 864, 1927.
2 P. R. Ray and H. G. Bhar, *Journ. Ind. Chem. Soc.*, **5**, 497, 1928.
3 D. M. Bose, *Phil. Mag.*, **5**, 1048, 1928.
4 P. K. Pillai, *Ind. Journ. Phys.*, **6**, 573, 1931.
5 S. W. Chinchalkar, *Phil. Mag.*, **20**, 856, 1935.
6 D. M. Bose and P. K. Raha, *Zeit. für Phys.*, **80**, 361, 1933.

into the mechanism of light absorption in paramagnetic compounds. A theory of the relation between the absorption spectra of paramagnetic compounds and their magnetic properties has been worked out by D. M. Bose and S. Datta [1]. Detailed experimental application and extension of this theory has been carried out by Datta [2]. His detailed investigations show how the magnetic and optical behaviour of ions are correlated. He has also studied the mechanism of quenching of orbital magnetic moments under different conditions in the iron group of ions.

An interesting observation was made by P. C. Mukherjee [3]. He investigated the absorption spectra of Nd^{+++} ions at liquid air temperatures and obtained evidence of lower excited levels at 249 cm^{-1} above the ground term. This is in fair agreement with the splitting of the ground term calculated by Penney and Schlapp, and is the first direct evidence in support thereof.

There is a class of paramagnetic substances of which the susceptibility is practically independent of temperature. D. P. Ray Chaudhuri and P. N. Sen Gupta [4] have investigated this class of compounds and shown that the atomic susceptibility of the magnetogenetic atom is not a constant, but depends on such factors as the intramolecular field, the crystalline field, etc.

In the field of low temperature Physics, paramagnetic substances have proved very useful. It is indeed by the demagnetisation of such substances that temperatures lower than that obtainable by any other means have been attained. The 'Characteristic temperature', (i.e., the temperature at which the freedom of rotation of spin axes gets severely restricted) of these paramagnetic substances play a very important rôle in determining their behaviour at such low temperatures. Krishnan [5] has shown that it is possible to predict the 'characteristic temperature' by measurements on the magnetic anisotropies of the substance at room temperature.

Ferromagnetism

Ferromagnetic substances are characterized by high magnetic permeability, which decreases suddenly above a temperature that is a characteristic of each substance and is known as its Curie point. Beyond this temperature the substance is paramagnetic. The special properties of the ferromagnetics were shown by Weiss to be due to a molecular field whose origin was a mystery till Heisenberg gave a satisfactory interpretation of it, basing upon the idea of the existence of an energy of interaction between electrons each of which is supposed to be associated with an atom in a crystal lattice. These electrons are not

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1 D. M. Bose and S. Datta, *Zeit. für Phys.*, **80**, 376, 1933.
2 S. Datta, *Phil. Mag.*, **17**, 585, 1934.
3 P. C. Mukherjee, *Ind. Journ. Phys.*, **11**, 123, 1937.
4 D. P. Ray Chaudhuri and P. N. Sen Gupta, *Ind. Journ. Phys.*, **10**, 245, 1936.
5 K. S. Krishnan, *Phil. Trans.*, **235**, 343, 1936.

permanently attached to their parent atoms, but have a finite probability of interchanging their positions. It is found that all ferromagnetic substances have a finite electrical conductivity, and the question arose whether all the electrons which take part with electrical conductivity in them are also carriers of ferromagnetism. Experiments performed on pure Nickel by Gerlach and his students showed that only a part of the conductivity is due to the ferromagnetic electrons, while the same result was proved for the semi-conducting ferrites by K. P. Ghosh [1]. D. P. Ray Chaudhuri [2] has studied the effect of tension in changing the Curie point of Nickel wires and thus verified some of the conclusions drawn by Slater on the dependence of the interaction energy on the interatomic distances in the crystal lattice.

Another interesting question which is not yet quite decided is whether the orbital moment of electrons contribute anything to the ferromagnetic phenomena. From gyromagnetic experiments made on metals the conclusion was drawn that only the spin moment of the electron contribute to ferromagnetism. Very careful experiments by Barnett have made it probable that the orbital moment of the electron contribute a small part to the effect, and this conclusion is supported by the investigation of D. P. Ray Chaudhuri [3] on the gyromagnetic effect in the ferrites.

VII. Optics and Raman Effect.

(a) *Diffraction Phenomena.*

An intensive study of diffraction phenomena was started by C. V. Raman in 1917, in collaboration with S. K. Mitra, N. M. Basu and others [4]. The phenomena of laminar diffraction, or diffraction at an edge where a transparent plate such as mica changes its thickness or refractive index was studied by P. N. Ghosh [5] and later by I. Ramakrishna Rao [6]. S. K. Banerji [7] made an important theoretical study of the Foucault test. T. K. Chinmayanandan [8] (since dead) studied Haidinger's rings. N. K. Sethi [9] studied interference and diffraction phenomena in liquids in which light of different colours travel with different velocities and showed the importance of the concept of group-velocity in dealing with such phenomena. The flow of energy when reflection takes place at the boundary between two transparent media and the colours of diffraction at metallic edges, have also been studied by Raman [10] and his

[1] K. P. Ghosh, *Zeit. für Phys.*, **68**, 566, 1931.
[2] D. P. Ray Chaudhuri, *Zeit. für Phys.*, **71**, 473, 1931.
[3] D. P. Ray Chaudhuri, *Ind. Journ. Phys.*, **9**, 383, 1935.
[4] C. V. Raman, *Phil. Mag.*, **21**, 618, 1911; S. K. Mittra, *Phil. Mag.*, **35**, 112, 1918; N. M. Basu, *Phil. Mag.*, **35**, 79, 1918.
[5–10] For references 5–10, see *Proceedings of the Indian Association for Cultivation of Science*, 1918–1922.

pupils. Working in Raman's laboratory, B. B. Ray[1] studied in 1920 and 1921 the colour and polarization of light scattered by colloidal suspensions of sulphur and made detailed calculations of the scattering of light by small transparent spheres of refractive index greater than unity and of diameter in the neighbourhood of the wavelength of the radiation. The problem is of great interest in meteorological optics.

In recent years, optical anisotropy of some organic crystals has been studied by S. Bhagavantam, K. L. Narasinham[2] and M. Ramanadham[3]. The Kerr effect in viscous liquids has been studied by S. C. Sircar[4] using radio-frequency oscillating field and the time lag has been determined. The anisotropy of optical polarization field in liquids has been studied by M. Ramanadham[5]. B. V. R. Rao[6] has studied the Doppler effect in light scattering in liquids by examining the structure of the Rayleigh line due to various liquids under different conditions with a Fabry Perot etalon. S. M. Mitra[7] has studied the polarization of fluorescence of dye solutions. S. S. Bhatnagar and D. L. Srivastava[8] have studied the optical inactivity of active sugars in absorbed state. Stress optical effect in overstrained celluloid has been studied by S. R. Savur.[9] Raman[10] has investigated the origin of colours of irridescent shells and found that the colours were due to diffraction effect.

(b) *The Raman Effect.*

Investigations on scattering of light were started in Calcutta by C. V. Raman in 1919. Since then, many workers have carried out investigations in this line of research in collaboration with him and under his guidance, and as a result of these investigations, a large number of papers dealing with the theoretical aspects as well as with experimental results have been published in various scientific journals of England, America, and India. Information regarding most of these papers is available from the bibliography[11] published in 1931. It may not be out of place, however, to mention a few of these papers which embody either notable contribution towards

[1] B. B. Ray, *Proc. Ind. Assoc. Cult. Sci.*, parts 1 and 2, 1, 1921.

[2] S. Bhagavantam, *Proc. Roy. Soc.*, **124**, 545, 1929; *Ind. Journ. Phys.*, **4**, 1, 1929.

[3] M. Ramanadham, *Proc. Ind. Acad. Sci.*, **1**, 425, 1935.

[4] S. C. Sircar, *Ind. Journ. Phys.*, **3**, 409, 1929.

[5] M. Ramanadham, *Proc. Ind. Acad. Sci.*, **1**, 281, 1934.

[6] B. V. R. Rao, *Proc. Ind. Acad. Sci.*, **1**, 675, 1935; **2**, 236, 1935.

[7] S. M. Mittra, *Zeits. f. Phys.*, **92**, 61, 1934.

[8] S. S. Bhatnagar and D. L. Srivastava, *Journ. Phys. Chem.*, **28**, 730, 1924.

[9] S. R. Savur, *Proc. Roy. Soc.*, **109**, 338, 1925.

[10] C. V. Raman, *Proc. Ind. Acad. Sci.*, **1**, 567, 1935; **1**, 859, 1935.

[11] S. Bhagavantam, *Ind. Journ. Phys.*, **5**, 303, 1931.

the theory of the phenomenon or experimental results of far-reaching importance.

Raman[1] put forward a new theory (1922) to explain the colour of the sea. Formerly, the colour was supposed to be due to reflection of blue sky light or due to suspended matter. According to the new theory it is due to molecular scattering of light. It was pointed out that in this case, the intensity of the molecular scattering of light calculated from the theory of fluctuation of density developed by Einstein and Smoluchowski agrees fairly well with observed values, and also the theories of previous workers were shown to be erroneous. K. R. Ramanathan[2] showed by examining the light scattered by different samples of sea water that the colour of the deep sea, where there is very little suspended matter, is practically the same as that of dust free water, and the colour changes to bluish green or green owing to the presence of suspended matter or some fluorescent matter in regions not far away from the land. The first detailed investigation of Raman[3] on the theory of light scattering in dense fluids was published in 1922. Subsequently, Raman and Ramanathan[4] investigated the same problem and showed that the Rayleigh law of scattering is applicable only to gases obeying Boyle's Law, and since this law is based on random distribution of molecules, it should not be applicable to dense fluids. Assuming the non-random distribution to be given by the Boltzmann's theorem, they deduced an expression for the scattering power per unit volume of the medium, which reduces to the Rayleigh Law for gases obeying Boyle's Law. The results thus deduced from the kinetic theory agree with those deduced by Einstein and Smoluchowski from thermodynamical theory of fluctuation of density. These authors[5] also revised Einstein's approximate investigation of scattering of light by liquid mixtures and showed by developing a rigorous formula that light scattering arises not only due to a spontaneous local fluctuation in the composition of the mixture, but also due to the local fluctuation of density. The effects of molecular anisotropy were also discussed.

Electro-magnetic theory of light-scattering was also developed by K. R. Ramanathan[6], but later Raman and Krishnan[7] developed a theory, which explains the facts more satisfactorily than previous theories. In this theory the polarization field acting on a molecule was assumed to be dependent on the orientation of the

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1 C. V. Raman, *Proc. Roy. Soc.*, **101**, 64, 1922.

2 K. R. Ramanathan, *Phil. Mag.*, **46**, 543, 1923.

3 C. V. Raman, Molecular diffraction of light, Calcutta University Press, 1922.

4 C. V. Raman and K. R. Ramanathan, *Proc. Ind. Assoc. Cult. Sci.*, 8, 1, 1923.

5 C. V. Raman and K. R. Ramanathan, *Phil. Mag.*, **45**, 213, 1923.

6 K. R. Ramanathan, *Proc. Ind. Assoc. Cult. Sci.*, 8, 1, 1924 ; 8, 181, 1924.

7 C. V. Raman and K. S. Krishnan, *Phil. Mag.*, **5**, [illegible], 1928.

molecule, i.e., the polarization field was taken to be anisotropic. With the help of this theory the authors were able to deduce an expression for the intensity of the scattered light which is in close agreement with observed values, and also they were able, in some cases, to calculate the depolarization of light scattered by the liquid from that of the vapour. Raman and Krishnan [1] also developed a theory of optical and electric properties of liquids taking into consideration the anisotropy of the polarization field.

In the experimental investigations on light-scattering carried out by Raman and his co-workers since 1919 till the end of 1927, the intensity and degree of depolarization of the light scattered by different substances under different conditions and in different states were measured. A systematic study of the depolarization of light scattered by about 60 liquids was first made by K. S. Krishnan [2] and later J. R. Rao [3] studied the light scattered by 63 vapours and gases. The study of depolarization of scattered light not only resulted in the determination of useful data and the verification of various theories, but also led to the discovery of the *Raman effect*.

Discovery

As early as 1921, Raman and K. S. Rao [4] observed that when sunlight is used as the incident light, the depolarization of the light scattered transversely by distilled water increases markedly when a violet filter is placed in the path of the incident beam. The effect was confirmed by Raman and K. S. Rao [5] by careful investigations. Ramanathan [6] showed, by systematic investigations, that the dependence of the depolarization of scattered light on wave-length of incident light was due to the presence of secondary radiation which was supposed by him to be 'weak fluorescence'. This 'fluorescence' could not be removed, however, even after careful chemical purification of the liquids. K. S. Krishnan [7] observed that out of 60 liquids studied by him, a large number exhibited this phenomenon. S. Venkateswaran undertook the investigation of the same problem in 1925, but got no definite results. When he resumed the investigation in 1928, he observed that the visible radiation excited in pure glycerine by the ultra-violet portion of sunlight transmitted through a corning glass light filter is strongly polarized. The significance of these results was not, however, fully realized till later it struck Raman that the phenomenon might be the optical analogue of the Compton effect. With this idea, he tried to investigate in collaboration with Krishnan whether in the scattered light any light

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1 C. V. Raman and K. S. Krishnan, *Proc. Roy. Soc.*, **117**, 598, 1928.

2 K. S. Krishnan, *Phil. Mag.*, **50**, 697, 1925.

3 I. R. Rao, *Ind. Jour. Phys.*, **2**, 97, 1927.

4 C. V. Raman, Rao and Sheshagiri, Molecular diffraction of light, Calcutta University Press, 1922.

5 C. V. Raman and K. S. Rao, *Phil. Mag.*, **45**, 633, 1923.

6 K. R. Ramanathan, *Proc. Ind. Assoc. Cult. Sci.*, 8, 190, 1923.

7 C. V. Raman and K. S. Krishnan, *Phil. Mag.*, **5**, 498, 1928.

of modified wave-length is present. In the preliminary investigations, sunlight was used as incident beam and two complimentary light filters, one blue-violet and the other green, were used. The green filter could cut off all the radiation transmitted by the blue-violet filter. The latter was placed in the path of the incident beam and when the green filter was placed in the path of the scattered light, all the scattered light could not be cut off, but a feeble green light was observed to be present. It was also observed that this green light was well polarized and very feeble, and hence it was concluded that this light was different from ordinary scattered light and fluorescent radiation and was due to a new kind of secondary radiation. This new radiation was observed by them in many liquids, solids and gases, and the universality of the phenomenon was proved.

The investigations were next repeated using light from mercury arc as the incident beam, and the scattering spectra were photographed with the help of a spectrograph. The spectrograms exhibited at once the presence of new lines of modified wave-lengths in the scattered spectra. It was observed that most of the modified lines were of degraded frequencies but a few were also present with enhanced frequencies. These observations were made on February 28, 1928, and announced the next day. The results of these investigations formed the subject of the inaugural address [1] delivered before the South Indian Science Association on March 16, 1928. It was mentioned in this address that the phenomenon could be explained by Kramers-Heisenberg theory of dispersion according to which part of the incident quantum can be absorbed by the molecule and the remaining part can be scattered giving a radiation of modified frequency ($\nu = \nu_0 \pm \nu_k$), and occasionally the energy of the molecule can also be given to the incident quantum, thereby giving rise to a scattered radiation of enhanced frequency. In subsequent communications it was pointed out by Raman and K. S. Krishnan [2] that the shifts of modified scattered lines correspond to the frequencies of vibration of the molecules, most of these frequencies being also observed in the infra-red absorption spectra. Later, it was pointed out [3] that the unmodified scattered line was in some cases accompanied by a continuous spectrum extending up to a few Angstrom units on each side, and it was suggested that rotation of the molecules might be responsible for the origin of this continuous 'wing'.

The phenomenon of presence of modified wave-lengths in scattered light mentioned above was called the *Raman effect* first by Pringsheim [4]. This phenomenon was also observed indepen-

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1 C. V. Raman, *Ind. Jour. Phys.*, **2**, 399, 1928.

2 C. V. Raman and K. S. Krishnan, *Ind. Jour. Phys.*, **2**, 399, 1928.

3 C. V. Raman and K. S. Krishnan, *Nature*, **122**, 82, 1928; **122**, 278, 1928.

4 P. Pringsheim, *Naturwiss.*, **16**, 597, 1928.

dently in crystals by Landsberg and Mandelstam [1], but they could not realize the universality of the phenomenon, and for this reason they restricted their investigations to crystals only and did not investigate liquids in which the phenomenon can be observed more easily. The discovery of the phenomenon attracted the attention of the scientists all over the world and investigations on Raman effect were started soon after the discovery in many other laboratories of Europe and America [2].

Further Investigations

The investigations on the Raman effect carried out so far in India relate to different aspects of the phenomenon, viz.: (1) theory, (2) experimental verification of theories, (3) experimental technique, (4) chemical constitution and the structure of the molecules, (5) effect of change of state and of other physical conditions on the phenomenon, and (6) the origin of modified continuous line spectra which are generally observed in the Raman spectra of liquids and solids respectively. Numerous papers dealing with these aspects of the Raman effect have been published from different laboratories in India. It will be beyond the scope of the present volume even to mention the names of all the authors and the titles of all these papers. Bibliographies of the papers published till the beginning of 1935 have, however, been published [3].

Theory of Raman Effect

As has already been mentioned, explanation regarding the origin of the phenomenon was given by Raman and by Raman and Krishnan in a series of papers and notes published just after the discovery of the Raman effect. A preliminary theory regarding the origin of the anti-Stokes (of enhanced frequency) Raman lines was first offered by Raman and K. S. Krishnan [4], who pointed out that these lines are due to induced emissions from initially excited states of the molecule, the feebleness of these lines being due to the fact that the ratio of the number of molecules in the excited state to that in the ground state is from thermodynamical considerations proportional to $e^{-h\nu/kT}$, where ν is the frequency of the line. The detailed theories of the vibrational as well as rotational Raman effect have been investigated by S. Bhagavantam [5] from classical point of view, from which information regarding the intensity and polarization of the lines can be obtained.

1 G. Landsberg and L. Mandelstam, *Naturwiss*, **16**, 557, 1928; *Compt. Rend.*, **187**, 109, 1928.

2 It is well known that the effect was predicted from thermodynamical reasoning by Smekal in 1923, but the discovery of Raman effect was a logical culmination of researches carried out in Raman's laboratory.

3 S. Bhagavantam, *Ind. Jour. Phys.*, **5**, 257, 1931; S. C. Sircar, *Ind. Jour. Phys.*, **7**, 431, 1932; S. C. Sircar and D. Chakravarti, *Ind. Jour. Phys.*, **9**, 553, 1935; J. H. Hibben, *Chem. Rev.*, **13**, 345, 1933; **18**, 1, 1936.

4 C. V. Raman and K. S. Krishnan, *Ind. Jour. Phys.*, **2**, 399, 1928.

5 S. Bhagavantam, *Ind. Jour. Phys.*, **6**, 331, 381, 557, 1933.

Experimental verification of theories

Besides the classical theories mentioned above, both classical and quantum mechanical theories of the Raman effect have been put forward by Manneback, Placzek and others which are accepted now-a-days as the most up-to-date theories of the phenomenon. Experiments have been carried out in other parts of the world as well as in India to test how far these theories can explain observed facts. The experiments carried out in India relate to the dependence of the intensity of the Raman lines on the incident frequency[1], the relative intensities of Stokes and anti-Stokes Raman lines[2], the angular distribution of intensity of Raman scattering[3], the relative intensities and polarization of rotational Raman lines of hydrogen[4] and of a few other substances, and the results generally agree with the polarisability theory except in a very few cases.

Experimental Technique

The technique originally employed at the time of the discovery of the Raman effect has been modified from time to time to suit the conditions of particular investigations. P. Krishnamurti[5] used a modified technique to investigate the Raman spectra of crystals and of highly coloured substances. N. N. Pal and P. N. Sen Gupta[6] used a continuous distillation apparatus in order to remove the fluorescent matter from some liquids and thereby were able to record the Raman spectra free from continuous background. Other improvements regarding the use of suitable light filters have also been made by some Indian workers, and the technique employed by R. Ananthakrishnan[7] for investigating the Raman spectra of solids may be mentioned in this connection.

Relation to Chemical Constitution and Molecular Structure

Most of the investigations on the Raman effect carried out in India relate to this particular aspect of the phenomenon and almost all the workers on Raman effect in India have investigated this particular aspect. The early work of Raman and K. S. Krishnan just after the discovery of the Raman effect dealt with this particular aspect. This work was pursued, and numerous organic and inorganic substances were studied under the guidance of Prof. Raman by a number of workers, viz., A. S. Ganesan, and S. Venkateswaran, S. Bhagavantam, P. Krishnamurti, S. Parthasarathy, S. C. Sirkar, N. Gopal Pai, C. S. Venkateswaran, R. Ananthkrishnan and a few others. Some of the above workers are still pursuing this line of

[1] S. C. Sircar, *Ind. Jour. Phys.*, **5**, 159, 593, 663, 1930 ; **6**, 133, 1931.
[2] S. C. Sircar, *Ind. Jour. Phys.*, **6**, 295, 1931 ; **8**, 67, 1933.
[3] D. P. Roy Chaudhuri, *Zeits. f. Phys.*, **72**, 242, 1931.
[4] S. Bhagavantam, *Ind. Jour. Phys.*, **7**, 107, 1932.
[5] P. Krishnamurti, *Ind. Jour. Phys.*, **5**, 1, 587, 1930.
[6] N. N. Pal and P. Sen Gupta, *Ind. Jour. Phys.*, **5**, 609, 1930.
[7] R. Ananthakrishnan, *Nature*, **138**, 803, 1936.

work independently. Investigations in this line have also been carried on in various laboratories of India by other workers, viz., J. C. Ghosh and co-workers, A. S. Ganesan and V. N. Thatte, N. N. Pal and P. N. Sen Gupta, S. K. K. Jatkar and a few others. The results of these investigations furnish data regarding the number of Raman lines, their frequency shifts, polarization characters and relative intensities, from which conclusions regarding the structure of the molecules and their chemical constitution have been drawn. The formation of co-ordination compounds has been studied with the help of Raman effect by D. M. Bose and S. Dutta[1].

Effect of Change of State and of other Physical Conditions

Investigations have been carried out to see how the Raman spectra of different substances undergo changes with change of state, and change of temperature, with dissolution in solvents and with the application of external electric field. Such investigations were started soon after the discovery and have been carried on from time to time; even at present some of the Indian workers are investigating problems of this kind. The effect of change of state was first studied by L. A. Ramdas[2] and later followed by many Indian workers. The influence of temperature was first studied by K. S. Krishnan[3] and later investigations of the Raman spectra at different temperatures, both high and low, have been carried on by most of the Indian workers. The investigations at low temperature are still being pursued by S. C. Sirkar and his co-workers. The first attempt to study electrolytic dissociation from Raman effect was made by I. Rama Krishna Rao[4]. S. K. Mukherjee and P. N. Sen Gupta[5] also investigated similar problem almost simultaneously. Hydrolysis and formation of complexes in liquid mixtures have been studied by P. Krishnamurti[6]. Very recently R. Ananthakrishnan[7] has studied the exchange reaction in the case of solution of ammonium chloride in heavy water.

Relation to Crystal Lattice

After the results of preliminary study of the Raman spectra of crystals had been announced by Prof. Raman, the Raman spectra of crystals were first studied in India by K. S. Krishnan[8], and later by I. Rama Krishna Rao[9]. The study of the Raman spectra of crystals of elements was first undertaken by C. Ramaswamy[10].

1 D. M. Bose and S. Dutta, *Nature*, **128**, 725, 1931.
2 L. A. Ramdas, *Ind. Jour. Phys.*, **3**, 131, 1928.
3 K. S. Krishnan, *Nature*, **122**, 650, 1928.
4 I. R. Rao, *Nature*, **124**, 762, 1929.
5 S. K. Mukherjee and P. N. Sen Gupta, *Ind. Jour. Phys.*, **3**, 503, 1929.
6 P. Krishnamurti, *Ind. Jour. Phys.*, **6**, 345, 401, 1931.
7 R. Ananthakrishnan, *Proc. Ind. Acad. Sci.*, **5**, 175, 1937.
8 K. S. Krishnan, *Nature*, **122**, 477, 1928.
9 I. R. Rao, *Ind. Jour. Phys.*, **3**, 123, 1928.
10 C. Ramaswamy, *Nature*, **125**, 704, 1930.

Later on S. Bhagavantam and P. Krishnamurti and a few other workers carried out some investigations in this line. The Raman spectra of crystals of many organic and inorganic compounds have been investigated by most of the Indian workers, and some of them, viz., R. Ananthakrishnan, J. Gupta, C. S. Venkateswaran and S. C. Sirkar and a few others are still pursuing these investigations.

Origin of Modified Continuous and Line Spectra in the neighbourhood of the Rayleigh Line

Several attempts have been made to investigate the origin of the 'wing' which accompanies the Rayleigh line in liquids. For this purpose, the intensity and polarization of the wing, the effect of change of temperature and of the change from the liquid state to vapour on the relative intensities and on distribution of intensities have been investigated. These investigations were first undertaken in India by S. P. Ranganadham [1] and later pursued by Bhagavantam and his co-workers and Sirkar and his co-workers. The results have led to the conclusion that in the case of the liquids the distribution of intensity is modified by the presence of intermolecular field. The origin of the Raman lines which appear close to the Rayleigh line in the Raman spectra of some organic crystals has also been investigated by studying the influence of temperature and of crystal lattice on the relative intensities as well as on frequencies of these lines. The results seem to indicate the presence in the crystals of polymerized groups or small 'clusters' having electronic bindings among constituent molecules, the intermolecular oscillations in these clusters being responsible for the origin of the lines mentioned above. These investigations were started in India by S. C. Sirkar [2].

VIII. Radio-activity, Nuclear Disintegration, Positive rays and Cosmic rays.

The work done in this important branch has been neither extensive nor systematic. It is probably due to the paucity of resources of the Indian Laboratories. In this report the work done in this country and by Indian workers in foreign countries will be reported under the following sections :—

(*a*) Radio-activity of rocks and hot springs and of the atmosphere ;
(*b*) Investigations with α and β particles ;
(*c*) Absorption and Scattering of γ-rays ; and
(*d*) Cosmic Rays and Positive Rays.

[1] S. P. Ranganadham, *Ind. Jour. Phys.*, 7, 353, 1932.
[2] S. C. Sirkar, *Ind. Jour. Phys.*, **10**, 109, 1936.

(a) *Radio-activity.*

In 1914, H. E. Watson and Pal[1] published a record of the investigation of the radio-active contents of rocks in the schists bored from gold-fields in Mysore. No relationship between depth and radio-active contents could be observed by these authors. N. C. Nag[2] investigated the radio-activity of columbite from Gaya district and of Allonite from Ranchi. Similar investigations on radio-active rocks have been carried out by Yajinik and Kohli[3]. The radio-activity of the spring water has also been the subject matter of several investigations. In Bombay Presidency Steichen[4] made a study of the radio-activity in the spring water from Tirwa. Mann and Paranjpe[5] studied the hot spring water from Ratnagiri. N. C. Nag[6] also investigated in detail the radio-activity of the hot spring at Ratnagiri. R. De[7] in 1925 gave a method for the separation of UrX from uranyl salts. His method is a modification of some standard methods. D. B. Deodhar[8] of Lucknow made a survey of atmospheric radio-activity in Northern India. It was found by him that the activity was greatest during the coldest part of the year, and the activity found in this country was much greater than that found by Simpson, Gockel and others in Europe. The reason of this, according to the author, is that the place of observation was inland and the nearest distance from the sea was about 600 miles. Estimate was also made by the author of the variation in the activity with the barometric pressure during different months in the year.

(b) *Investigations with α and β Particles.*

In this section we give an account of a number of investigations made by D. M. Bose[9] in Germany during 1915–1917 in Regener's Laboratory in Berlin. In this investigation tracks of α-particles were photographed in different gases, in a Wilson's expansion chamber made of glass, in which the expansion was made by a magnetic release. The ionization tracks of recoil H-particles due to collisions with α-particles, as predicted by Darwin, were photographed for the first time and the angular distribution was shown to be in accordance with theory. Further the tracks of δ-particles were photographed almost simultaneously with Bumstead. The

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1 H. E. Watson and Pal, *Phil. Mag.*, **28**, 44, 1914.

2 N. C. Nag, *Jour. of Geological, Mining and Metallurgical Soc. India*, **11**, 1920; N. C. Nag, *Malaviya Commemoration Vol.*, 778, 1932.

3 Yajinik and Kohli, *Jour. Chem. Soc. London*, **126**, 620, 1924.

4 Steichen, *Phil. Mag.*, **31**, 401, 1916.

5 Mann and Paranjpe, *Jour. Roy. Asiatic Soc.*, 1916.

6 N. C. Nag, *Trans. Bose Institute*, **7**, 319.

7 R. De, *Sc. Assoc. Maharajas College Vizianagram*, Oct. 1925 also *Jour. Chem. Phys.*, **23**, 197, 1926.

8 D. B. Deodhar, *Proc. Roy. Soc.* A, **109**, 280, 1925.

9 D. M. Bose, *Phys. Zeit.*, **17**, 388, 1916; *Zeit. f. Phys.*, **12**, 207, 1922.

ionization tracks of particles from Ra E were also studied and the problem of simple and multiple scattering of these particles and the ejection of secondary electrons were studied. It was also noticed that when particles were incident on the surface of a mica screen, the ionization tracks showed some anomalous behaviour. This problem was later taken up by H. P. De[1] who gave a satisfactory explanation of the observed effect. D. M. Bose[2] continued this line of investigation after his return to India. In a paper published in collaboration with S. K. Ghosh[3] the tracks of radio-active recoil atoms were photographed in hydrogen under reduced pressure and the high ionising power and the scattering of these recoil atoms were observed. In a letter published in *Nature*, the same authors gave some photographs of α-particles in Helium. In some of them pairs of recoil δ-particle tracks were shown, pointing to the simultaneous ejection of two electrons from Helium atom; probability of such ejection had been studied by Millikan using the oil drop method. Another photograph was given, which was interpreted as representing the disintegration of a nitrogen atom. S. K. Ghosh[4] gave a detailed account of these investigations.

M. S. Krishnan and Mahadevan[5] in course of investigations with cordierite (a double refracting crystal) gave an explanation of the Giant pleochoric haloes observed in them as being due to the long range of α-particles from Ra C′ and Th C′ enclosed in the material.

R. Naidu[6] has made a fresh study of the ionization curve of α-particles. It has been shown in this paper that Bragg's curves are to some extent falsified by multiple scattering. With the new apparatus due to this author, the ranges of α-particles from Po and Ra C′ were examined. The author[7] notes that for Helium and Neon the loss of energy of the α-particle was entirely due to ionization, whilst in the Argon and Air a large portion of the loss was due to the excitation and dissociation of the molecules. The same author[8] has published similar investigations on Bragg's curve for Krypton and Xenon and the results were compared with those found for Helium and Air. In continuation of the previous work Naidu has calculated the stopping power of the rare gases and the velocities corresponding to the maximum ionization were evaluated.

Taylor and Dabholkar[9] have published results about the ranges of α-particles in photographic emulsions. Numerous

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[1] H. P. De, *Phys. Rev.*, **30**, 960, 1927.
[2] D. M. Bose, S. K. Ghosh, *Phil. Mag.*, **45**, 1050, 1923.
[3] D. M. Bose, S. K. Ghosh, *Nature*, **111**, 463, 1923.
[4] S. K. Ghosh, *Bull. Cal. Math. Soc.*, **17**, 99, 1926.
[5] M. S. Krishnan and S. Mahadevan, *Ind. Jour. Phys.*, **5**, 669, 1930.
[6] Naidu, *Ann de Physique*, **1**, 72–122, 1934.
[7] Naidu, *J. de Physique et le Radium*, **5**, 343, 1934.
[8] Naidu, *J. de Physique et le Radium*, **5**, 575, 1934.
[9] Taylor and Dabholkar, *Phys. Soc. Proc.*, **48**, 285, 1936.

particle tracks on Ilford plates were measured, from which the extrapolated range was determined. This method was also employed to determine the ranges of the particles produced by the disintegration of Boron and Lithium under slow Neutron bombardment. Samarium was investigated by this method and the ranges of the α-particles emitted from it were determined.

The same authors[1] have studied the ranges of particles emitted by Thorium series by the previous method. Radio-Thorium was introduced into the emulsion and actually five tracks emanating from a point were found, these tracks are ascribed to the five different types of particles emitted by the subsequent disintegration products of Radio-Thorium.

(c) *Absorption and Scattering of γ-rays.*

The true absorption co-efficient of γ-rays was investigated by Duane and Majumdar[2] who gave an empirical formula for this coefficient.

A series of investigations on absorption and scattering of rays were made by N. Ahmad[3]. In the later paper the absorption of γ-rays from Ra B and Ra C, filtered through different thicknesses of several elements have been measured by a modified balance method. For each element the atomic absorption coefficient were found to be represented by AZ and BZ^4, where A and B are constants for a particular beam. The first term represents the scattering absorption and the second part the fluorescent absorption. This shows that the absorption of γ-rays follows the same general laws as that of X-rays. Using an ionization chamber capable of revolution about the radiator the intensities of the scattered rays were measured. The observed values were found to agree well with Compton's formula.

It has been found that γ-ray in its passage through foils of heavy elements gives rise to positron and electron pairs. This has formed the subject of investigation by Dixit[4] in collaboration with Bewilogua. A uniform magnetic field was employed to analyse the energies of the electrons and positrons emitted from their metal foils when subjected to γ-rays. The ratio of the yield of electron to positron was calculated for Pb, Ag and Al. The values were found to be independent of foil thicknesses but proportional to the atomic number. Further in order to study the absorption of the corpuscles (+ and −), foils of different thicknesses were placed before the photographic plates, and a relation between blackening and foil thicknesses was obtained. It was found that for ·3 gm.-

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[1] Taylor and Dabholkar, *Proc. Ind. Acad. Sci.*, **3A**, 265, 1936.
[2] Duane and Majumdar, *Nat. Acad. Sci. Proc.*, **8**, 45, 1922.
[3] N. Ahmad, *Proc. Roy. Soc.*, A, **105**, 507, 1924; **106**, 8, 1924; and **109**, 206, 1925.
[4] Dixit and Bewilogua, *Phys. Zeits*, **35**, 699, 1934.

cm [2] of Pb there was a complete absorption of both the positrons and electrons. It was further found that the secondary radiations were three times greater in the case of positron than those for electrons and this was clearly due to the annihilation of the positrons.

Production of positrons from Bismuth was the subject matter of the investigation by H. P. De [1]. This paper gives an account of the study of the emission of the positrons from Bismuth due to absorption of radiations and neutrons emitted from a tube containing a mixture of Mesothorium and Beryllium Oxide. The apparatus used was a cloud chamber placed in a magnetic field. A thin aluminium sheet was employed to observe the direction of ejection and nature of the corpuscle emitted. Electron positron ratio as well as the energy range of the positrons were determined. The conclusion drawn from this study was that the main source of positron is the pair formation. A photograph of the electron positron pair has been reproduced in the paper.

(*d*) *Cosmic rays and Positive rays.*

Cosmic rays

The study of cosmic rays was initiated in this country by A. H. Compton when he came to Lahore as visiting professor in 1926. Later on he inaugurated a world wide survey of the intensity distribution of the cosmic rays, in which standardized instruments were given to observers in different parts of the earth. J. M. Benade [2] of Lahore measured the intensity at Ladhak, Lahore, Ceylon and Java. Another fruitful line of investigation is to measure the east and west asymmetry of the cosmic radiation at different latitudes and altitudes, from which conclusions can be drawn as to the nature and charge of the particles contained in the original cosmic ray beam. Further according to a calculation of Lemaitre an asymmetry in the north and south distribution of cosmic rays at different zenith angles as a function of latitude and altitude is to be expected. R. Ghosh [3] has commenced investigations on these east and west and north-south asymmetries in Calcutta and Darjeeling. R. Ghosh has also published some investigations (1936) on the intensity of production of showers by cosmic rays in different materials as a function of the thickness.

It was noted by Kohlhörster that at the period of maximum brightness of Nova Hercules during the middle of December, 1936, the intensity of cosmic radiation as measured by a G. M. Counter was increased appreciably. On the other hand a number of observers at different places and altitude using Stienke's ionization recording apparatus could not detect any increase in the intensity of cosmic radiation, during the period of activity of Nova Hercules.

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[1] H. P. De, *Ind. Jour. Phys.*, **10**, 2, 103–108, 1935.
[2] J. Benade, *Phys. Rev.*, **42**, 290, 1932.
[3] R. Ghosh, *Science and Culture*, Feb., 1936.

Dr. A. K. Das [1] however reported from Cambridge Solar Physics Laboratory, results obtained by means of a continuously recording electrometer taken during the period February 14 to March 20, which indicated an increase in the intensity of cosmic rays during the hours when Nova Hercules was at its greatest altitude, in conformity with Kohlhörster's observation.

Positive rays

B. Dasanacharya [2] has made an important contribution on the light emission from the moving atoms of Hydrogen Canal rays and in this paper several important conclusions have been drawn. R. Ghosh [3] whilst working in Geiger's Laboratory made systematic absorption measurements of the protons in different substances.

IX. Spectroscopy.

Bohr's theory of hydrogen spectrum (1913) opened out new fields of research in spectroscopy and scientists in India as in other countries became conscious of the importance of research in spectroscopy. The first Indian worker of note in this line was S. Datta [4], who working in the laboratory of the Imperial College of Science under the guidance of Prof. A. Fowler, performed experiments with sodium and potassium vapours. He obtained a large number of lines in absorption, and determined the wave-lengths of series lines with great accuracy, and obtained accurate values of the series limit of these elements. He also obtained the 1*s*-m*d*, 1*s*-m*s* lines of potassium in absorption—a result of great theoretical value in atomic physics as these lines are forbidden according to the Bohr-Sommerfeld theory. Metcalfe and Venkatesachar [5], working with mercury vapour in a specially designed tube in which normal Hg-atoms were electrically excited by a low discharge, obtained absorption lines due to Hg-atoms in an excited state. N. K. Sur and R. N. Ghosh [6] obtained similar absorption with potassium vapour by temperature excitation at 1400°C. At this time owing to the publication of Catalan's paper on classification of lines of Mn and the work of Sommerfeld and his school on the classification of complex spectra, a good deal of interest was excited in the spectroscopy of complex elements. Indian workers were not slow to make their contributions. A. L. Narayan [7] in collaboration with

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1 A. K. Das, *Nature*, **129**, 136, 1935.
2 B. Dasanacharya, *Ann. d. Physik*, **77**, 597, 1925.
3 R. Ghosh, *Tübingen Dissertation*, 1934.
4 S. Datta, *Proc. Roy. Soc.*, **99**, 69, 1921; **101**, 539, 1922.
5 E. P. Metcalfe and B. Venkatesachar, *Proc. Roy. Soc.*, **100**, 149, 1921.
6 N. K. Sur and R. N. Ghosh, *Phil. Mag.*, **49**, 60, 1925.
7 A. L. Narayan and D. Gunnayya, *Phil. Mag.*, **45**, 831, 1923. A. L. Narayan, D. Gunnayya and K. R. Rao, *Proc. Roy. Soc.*, **106**, 596, 1924. A. L. Narayan and G. Subramanyam, *Ind. Assoc. Cult. Sci. Proc.*, **9**, 15, 1924.

D. Gunnaya and K. R. Rao studied the absorption of potassium and thallium vapours and with G. Subramanyam studied the spectrum of K-vapour made electrically luminiscent. After this there followed a series of papers [1] on the absorption spectra of elements: thallium and Indium (K. R. Rao), lead and tin (Sur and Sharma), aluminium and cobalt (Sur and Majumdar), iron (Sur), Ni (Majumdar), lead, tin, bismuth and magnesium (Narayan and Rao), Ni (Narayan and Rao).

After the publication of Hund's theory of complex spectra, M. N. Saha [2] applied the idea for an interpretation of the spectrum of neon. He explained the nature of the combination and accounted for not only the fundamental levels but also the higher levels obtained by Paschen, Rydberg sequence and the order of values obtained in each case. He also explained the origin of dashed terms and gave interpretation of such transitions and showed that they do not break the selection principle. Saha and Kichlu [3] summarized the properties of the spectra of metals belonging to group II of the periodic table and extended the irregular doublet law in the optical region even for spectra giving multiplet structure. Saha and K. Majumdar [4] instituted the method of horizontal comparison for the location of spectra, a method which proved helpful in locating the position of a particular transition while classifying the lines of a complicated spectrum.

The following is, in brief, a list of classification of series spectra done by Indian workers [5] :—

N. K. Sur .. .	Pb I, Sn I.
P. K. Kichlu .. .	Cu I, Si II, Kr II.
K. Majumdar .. .	Ag II, Na II, Cl I.
K. Majumdar and S. C. Deb	Cl III.
G. R. Toshniwal .. .	Bi I.
D. K. Bhattacharyya .	S II.
S. C. Deb .. .	Br II, III, IV, V, Cl IV, Cl V, I (iodine) I.
S. C. Deb and A. K. Dutta .	A II, Kr II.
S. C. Deb and M. Mohanti .	Te II.

1 K. R. Rao, *Proc. Phys. Soc.*, **37**, 259, 1925.
N. K. Sur and R. K. Sharma, *Sci. Assn. Maharaja's College, Vizianagram*, **1**, 121, 1924.
N. K. Sur and K. Majumdar, *Phil. Mag.*, **1**, 451, 1926.
N. K. Sur, *Phil. Mag.*, **1**, 433, 1926.
K. Majumdar, *Zeits. f. Physik*, **39**, 562, 1926.
A. L. Narayan and K. R. Rao, *Proc. Phys. Soc.*, **38**, 354, 1926.

2 M. N. Saha, *Phil. Mag.*, **4**, 223, 1927.

3 M. N. Saha and P. K. Kichlu, *Phil. Mag.*, **4**, 193, 1927.

4 M. N. Saha and K. Majumdar, *Ind. Jour. Phys.*, **3**, 67, 1928.

5 For references to original works up to 1930, see Goudsmit and Bacher: *Introduction to atomic spectra.* For later works consult *Science Abstracts.*

D. S. Jog	C I.
D. G. Dhavle	P II, Sb II.
A. L. Narayan	Pb II, Pb III.
A. L. Narayan and K. R. Rao	Sn II.
A. S. Rao and A. L. Narayan	As III, Pb III, Tl III.
K. R. Rao	Sn III, As I, As II, III, IV, Sb III, Te IV, V, VI, Br V, VI, VII.
Rao, Narayan and Rao ..	Sn IV.
K. R. Rao and J. Badami ..	Se IV, V, Se III.
K. R. Rao and Krishnamurti	Se II.
S. G. Krishnamurti ..	Te III.
S. L. Malukar ..	As I.
Pathabhiramiah and A. S. Rao	As III, Tl III.
J. S. Badami	Ce IV, Sb IV, V.
B. Venkatesachar and T. S. Subbaraya	Hg II.
D. P. Acharyya	Kr IV.
P. N. Kalia	Ce III.
A. S. Rao	As I, Se III, As II.
B. V. R. Rao	Au II, Ag III, Cu III.
Mela Ram	K III, IV, V, VI, Ca IV, V.

K. R. Rao and J. S. Badami[1] working with As in the Schumann region in an atmosphere of hydrogen observed a change in the intensity of hydrogen lines. They showed that the lines of hydrogen spectrum having the energy corresponding to the excitation potential of As are greatly enhanced in presence of As at a very low pressure. S. C. Deb[2] was able to perform absorption experiments on I-atoms produced by thermal dissociation of I_2 and thus identify some of the resonance lines of I. Further, he was able to photograph the continuous spectrum of the iodine atom obtained as a result of recombination of a free electron with the once ionized iodine atom in an excited state. S. Dutta and P. C. Bose[3] found the satellites of the third and the fourth members of the diffuse series in the spectrum of Rb and showed that the D-levels are double as theoretically expected.

The measurement of wave-lengths to serve as standard is of importance in spectroscopy. In this connection, mention may be made of the work at the laboratory of Prof. Ch. Fabry done by S. K. Mitra[4] who made some standard measurements of the arc lines of copper in the ultraviolet.

[1] K. R. Rao and J. S. Badami, *Proc. Roy. Soc.*, **138**, 540, 1932.
[2] S. C. Deb, *Proc. Roy. Soc.*, **139**, 380, 1933.
[3] S. Dutta and P. C. Bose, *Zeits. f. Physik*, **97**, 321, 1935.
[4] S. K. Mittra, *Annales de Physique*, **19**, 315, 1923.

Hyperfine Structure of Spectral Lines

Wali Mohammad[1], working in Göttingen in Germany, carried out in 1912 some standard work on the hyperfine structure of the arc lines of bismuth and other elements. His work showed that many bismuth lines consist of a number of components separated by very small intervals. These works were the foundation on which the subsequent superstructure of works on hyperfine structure, now regarded as essential for work on Nuclear Physics, was built up. On his return to India Wali Mohammed[2] continued his work at Lucknow and in collaboration with Sharma and Mathur he made measurements of some of the lines in the arc spectra of bismuth, silver and zinc, tin and lead.

Metcalfe and Venkatesachar[3] studied the selective absorption of the components of the green line of mercury and considered the possible isotopic origin of some of the satellites.

Venkatesachar[4] made a similar study with blue line ($\lambda 5086$) of Cd I and found that the component $+0{\cdot}106$ cm^{-1} showed stronger selective absorption than component $0{\cdot}290$ cm^{-1}.

Venkatesachar and Sibaiya[5] have examined the hyperfine structure of 10 lines in the arc spectrum of platinum and determined the isotopic constitution and nuclear spin of the element. By an analysis of the microphotograms, they also determined the relative abundance of the different isotopes. They have also made a similar study of the *hfs* of some of the significant arc lines of Ir and concluded that it consists of two isotopes 191 and 193 with a relative abundance of 1 : 2. S. K. Mukerjee[6] has made similar measurements of some of the spark lines of arsenic.

Badami[7] has measured the hyperfine structures of a series of Sb II lines excited in a vacuum arc lamp and also of some ultraviolet arc lines of Sb. In the case of the former he has tried to explain the structures by assuming a nuclear moment of $I = \frac{5}{2}\frac{h}{2\pi}$ for the more abundant isotope Sb^{121} and nuclear moment of $I = \frac{7}{2}\frac{h}{2\pi}$ for the isotope Sb^{123}. His measurements have enabled him to extend and correct the series analysis of Sb II lines.

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1 Wali Mohammad, *Dissert. Göttingen*, 1912.

2 Wali Mohammad and S. B. L. Mathur, *Phil. Mag.*, **4**, 112, 1927; **5**, 1111, 1928; **14**, 270, 1932.
Wali Mohammad and P. N. Sharma, *Phil. Mag.*, **10**, 916, 1930; **12**, 726, 1931; **12**, 1106, 1931; **14**, 977, 1932; **14**, 1143, 1932; *Ind. Jour. Phys.*, **6**, 75, 1931.

3 E. P. Metcalfe and B. Venkatesachar, *Proc. Roy. Soc.*, **105**, 520, 1924; **2**, 101, 1935; **2**, 203, 1935.

4 B. Venkatesachar, *Zeits. f. Physik*, **75**, 676, 1932.

5 B. Venkatesachar and L. Sibaiya, *Ind. Ass. Sci. Proc.*, **1**, 955, 1935; **2**, 101, 1935; **2**, 203, 1935.

6 S. K. Mukerjee, *Ind. Jour. Phys.*, **20**, 213, 1937.

7 J. S. Badami, *Zeits. f. Physik*, **79**, 206, 1932; **79**, 224, 1932.

The hyperfine structures of about 20 important As II lines in the region 6300 Å to 4300 Å have been investigated by A. S. Rao [1], who found the nuclear spin of the element to be $\frac{3}{2} \frac{h}{2\pi}$. He also found that the *f* selection rule, the interval rule and the intensity rule were generally valid.

The work of Venkatesachar [2] on the spectrum of mercury arc is interesting and worth noting. In one of his experiments, he studied the effect of altering the density of the vapour of the arc on the relative and absolute intensities of the lines radiated by it and found that lowering of the density increases the absolute intensity of all lines below $m=5$ and diminishes that of all lines above $m=6$, concluding thereby that inelastic collisions between excited atoms in lower energy levels and thermally energetic normal atoms form the chief source of radiation of the higher member of the series. In another experiment, Venkatesachar [3] studied the influence of the length of the radiating column on the width of spectral lines.

X. Theoretical Physics.

M. N. Saha [4] published a paper on Maxwellian stresses in which it was shown that the interpretation of certain Maxwellian Functions as representing stresses in medium (Aether) having the properties of an elastic solid is misleading and leads to confusion. M. N. Saha and S. N. Bose [5] later deduced a new equation of state. In a number of papers, M. N. Saha [6] applied the principle of special relativity to deduce the Lienard-Wiechert expression for potential of a moving electron, and for deducing the Clausius Law of Kinetic Potential to express the interaction between two moving electrons.

S. N. Bose [7] succeeded in deducing Planck's Law of Black-body radiation by considering directly the statistics of an assembly of photons in a six-dimensional phase space according to a method which was later extended by Einstein to an assembly of material particles. It is well known that Bose's work introduced a new method in quantum statistics which has received the name of Bose-Einstein Statistics, and was responsible for stimulating the work of Fermi and Dirac on the alternative statistics which apply to most elementary material particles (Fermi-Dirac Statistics).

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1 A. S. Rao, *Zeits. f. Physik*, **84**, 236, 1933.
2 B. Venkatesachar, *Proc. Roy. Soc.*, **117**, 11, 1927-28.
3 B. Venkatesachar, *Phil. Mag.*, **49**, 33 (1925).
4 M. N. Saha, *Phil. Mag.*, **33**, 256, 1917.
5 M. N. Saha and S. N. Bose, *Phil. Mag.*, **36**, 199, 1918.
6 M. N. Saha, *Phil. Mag.*, **36**, 76, 1918; *Phys. Rev.*, **13**, 34, 1919; *Phil. Mag.*, **37**, 347, 1919.
7 S. N. Bose, *Zeits. f. Physik*, **27**, 384, 1924; K. C. Kar, *Phys. Zs.*, **28**, 300, 1927.

K. C. Kar and his co-workers R. C. Majumdar, A. Ganguli and Mukherji[1] have shown that from Gibb's system of statistical mechanics it is possible to deduce many old and new results, viz. :—Planck's radiation formula with the help of Bothe's quantum molecules; Statistics of Bose-Einstein and Fermi-Dirac; wave statistics with application to radioactivity; formula for adsorption given by Langmuir and general results in colloid chemistry.

M. N. Saha and R. K. Sur[2] applying Ehrenfest's method of Phase Volume obtained a correction to Saha's equation for a non-isothermal gas system. The same equation has also been obtained by Jaikishen[3] in a simpler way; he has also discussed the phenomena of annihilation and pair generations as a special case of dissociation.

M. N. Saha and R. C. Majumdar[4] further modified the Gibbs-Ehrenfest's method in which it was assumed that the probability of realizing a state was proportional to the total 6N dimensional phase space and obtained the statistics of Bose-Einstein and Fermi-Dirac in an *anschaulich* way. S. Chandrasekhar[5], D. S. Kothari and R. C. Majumdar[6] attempted to work out a second approximation of Planck's formula. Though under ordinary circumstances the correction is negligible, it may find important applications in the physics of metals at very low temperature when the lattice vibrations in electric field are not in exact thermal equilibrium due to Peierl's Umklapp process. R. C. Majumdar[7] developed systematically a relativistic quantum statistics and deduced the formula for Energy, Pressure, Entropy, etc., of a non-degenerate as also of degenerate gas system; the results being intensively used in astrophysics. D. S. Kothari[8] investigated the problem of Döppler and Compton effects in a very general way from the quantum theory of light and discussed their interrelations in an interesting way. In collaboration with B. N. Srivastava Kothari[9] discussed the Wiens Radiation Law and the pressure of light from the same view point.

M. Born and N. S. N. Nath[10] gave an exposition of the Neutrino theory of Light—first proposed by de Broglie, Jordan and Krönig. On the assumption that neutrinoes satisfy the Fermi-

[1] K. C. Kar and R. C. Majumdar, *Zs. f. Phys.*, **55**, 546, 1929; K. C. Kar and K. K. Mukherji, *Zs. f. Phys.*, **59**, 102, 1929; K. C. Kar, *Phil. Mag.*, **21**, 1067, 1936; K. C. Kar and A. Ganguli, *Phys. Zs.*, **30**, 918, 1929.

[2] M. N. Saha and R. K. Sur, *Phil. Mag.*, **1**, 281, 1926.

[3] Jaikishen, *Ind. Jour. Phys.*, **10**, 389, 1936.

[4] M. N. Saha and R. C. Majumdar, *Phil. Mag.*, **9**, 584, 1930.

[5] S. Chandrasekhar, *Phys. Rev.*, **34**, 1205, 1929.

[6] D. S. Kothari and R. C. Majumdar, *Zs. f. Phys.*, **61**, 538, 1930.

[7] R. C. Majumdar, *Astro. Nach*, **242**, 145, 1931.

[8] D. S. Kothari, *Phil. Mag.*, **8**, 55, 1929; *Ind. Jour. Phys.*, **4**, 575, 1930.

[9] B. N. Srivastava and D. S. Kothari, *Ind. Jour. Phys.*, **3**, 493, 1929.

[10] Born and Nagendranath, *Ind. Acad. Sci.*, 3A, 318, 1936; Nagendranath, *ibid.*, 448, 1936.

Dirac statistics, it was shown that photons satisfy the Bose-Einstein statistics. The Planck formula was also deduced. Nagendranath further introduced the spin of the neutrino in order to obtain two photon operators for such energy state of photons and derived the Planck's formula; these two operators being connected with the polarization states of light.

In the field of atomic physics, S. C. Kar [1] suggested an alternative form of quantum condition as against the one put forward by Bohr-Sommerfeld. Though his results were identical with those of Sommerfeld in the particular cases of linear oscillator, the rotator, and the ordinary Newtonian ellipse they were at variance with both for the relativistic ellipses. Though the components of the Balmer lines of Hydrogen received no direct explanation in this theory, the behaviour of the Rydberg number could be regarded as somewhat more satisfactory. Applying Sommerfeld's quantum condition, S. N. Bose [2] studied the energy spectrum of an atomic model in which the field acting on the electron was due to the superposition of Coulombian field of attraction with that of a dipole. He was thus able to account for Rydberg sequence in a general way. K. Basu investigated the energy spectrum in a Bose model of atom as an *eigenwert* problem of wave equation of Schrödinger. K. Basu [3] also developed a mathematical method with the application of infinite determinants to calculate the *eigen* values in general, and successfully applied it to calculate the higher order Stark effect in the Balmer lines of Hydrogen and also to study the perturbation effect in the energy of a diatomic molecule. S. K. Chakravorti [4] calculated the *eigen* value for a field under two centres of force and found a Ritz type formula. He further studied the fundamental frequencies of NH_3 Bands from wave mechanics, the molecule being regarded as symmetrical top of pyramidal form having N at the apex and H at each centre of equatorial base. B. S. Ray [5] studied by Matrix mechanics the dependence of *eigen* values of the moments of inertia of an asymmetrical rotator. Mention may be made of the works of P. Das [6] on the polarization and intensity in the complex Zeeman effect. He also calculated the term values and the heat of dissociation of the diatomic molecules LiH, BeH and I_2 by a method due to Hylleras.

N. R. Sen [7] employed the theory of Dirac and Darwin to study the splitting up of hydrogen lines in parallel and in crossed

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[1] S. C. Kar, *Phil. Mag.*, **45**, 610, 1923.

[2] S. N. Bose, *Phil. Mag.*, **40**, 619, 1920.

[3] K. Basu, *Zs. f. Phys.*, **63**, 304, 1930; **64**, 708, 1930; *Bull. Cal. Math. Soc.*, **26**, 79, 1934; *Ind. Phys. Math. Jour.*, **4**, 1, 1933.

[4] S. K. Chakravorti, *Ind. Phys. Math. Jour.*, **5**, 25, 1936; *ibid.*, **6**, 31, 1935.

[5] B. S. Ray, *Zs. f. Phys.*, **78**, 74, 1932.

[6] P. Das, *Ind. Phys. Math. Jour.*, **3**, 115, 1932; *Ind. Jour. Phys.*, **9**, 35, 1934.

[7] N. R. Sen, *Zs. f. Phys.*, **56**, 673, 1929.

electric and magnetic fields. When the fields are parallel the results are the same as those produced with the old form of quantum mechanics. For crossfield the result is complicated, and a diagram has been proposed showing the manner in which the hydrogen lines are split up. The effect of non-homogeneous electric field on the fine structure of hydrogen-like atoms has been investigated thoroughly by S. Gupta [1] from the two component wave equations given by Darwin. He finds that though all the fine structure levels except the lowest one split up into several components, in practice only a broadening of the line is to be expected, the separation being extremely small to be resolved. M. N. Saha and A. C. Banerjee [2] used Dirac's theory in the form developed by Darwin and Weyl to calculate the transition probabilities of the fine structure components of series lines of hydrogen and ionized helium. The Ornstein-Burger-Sommerfeld rule for the relative intensities of the components of a multiplet was deduced as a result of this work.

Some interesting investigations have also been carried out regarding the physical properties of the 4-matrices occurring in the relativistic wave equation for electron put forward by Dirac. N. R. Sen [3] extended Schrödinger's interpretation of the Dirac matrices α_1, α_2 and α_3 to α_4. The Matrix α_4 is investigated in detail and a geometrical interpretation is given. It was shown that it does not represent an independent idea or property, but can be described in terms of various field vectors. The impulse and the energy equation for the motion of an electron with relativity correction have been deduced by N. R. Sen from Dirac's equation; the expression for the Lorentz force was also obtained. Following Sen, S. Gupta [4] deduced the equations for impulse moment, and virial from Dirac's four equation system. It was found that the classical expressions for impulse moment must be completed by a term which corresponds to the spin of the electron. Gupta then examined these two equations to see how far the correspondence with Frenkel's electron having electric and magnetic moments can be maintained. It was found that Dirac's electron in general yields some more extra terms which cannot be easily expressed in terms of classical quantities and when under suitable conditions these vanish a virial equation of exactly the form given by Frenkel is obtained. In an interesting paper, Gupta [5] further deduced the mathematical analogy between the free electron and electromagnetic waves from a consideration of the operators themselves in Schrödinger's calculus of operators relating to α-matrices. K. C.

[1] S. Gupta, *Zs. f. Phys.*, **66**, 246, 1930.
[2] M. N. Saha and A. C. Banerjee, *Zs. f. Phys.*, **68**, 704, 1931.
[3] N. R. Sen, *Ind. Phys. Math. J.*, **2**, 1, 1931; *Zs. f. Phys.*, **66**, 122, 1930; *Zs. f. Phys.*, **68**, 267, 1931.
[4] S. Gupta, *Zs. f. Phys.*, **68**, 573, 1931; *Ind. Phys. Math. J.*, **3**, 105, 1932.
[5] S. Gupta, *Zs. f. Phys.*, **82**, 408, 1933.

Kar[1] showed how the fine structure formula for hydrogen lines, identical with that as obtained from Dirac's relativistic equation, can be deduced from Schrodinger equation when the Thomas correction is introduced in it. S. C. Kar[2] developed a simple group theory method of calculating the valency states of an atom using Slater's method of introducing the spin function.

In the domain of modern metal physics, R. C. Majumdar[3] examined the conductivities of metals and semi-conductors from a unitary mathematical point of view both for deformable and rigid ionic models of Bloch and Nordheim and found that they give almost identical results. He also proposed a model of liquid metal in which it is assumed that in the liquid state, because of the high temperature, the regular distribution of the ions in the form of the lattice is destroyed and the whole system behaves like a gas mixture of electrons and ions distributed at random. The expressions for conductivities, Thomson co-efficient, optical constants, etc., have been worked out and the results are in fairly good agreement with the observations. N. K. Saha[4] studied the change of resistance of metal due to pressure both for high and low temperatures. M. Sen Gupta[5] worked out in detail the change of resistance of semi-conductors in magnetic field under the assumption of Lorentz force acting on the metal electron and shows that quantitative agreement with the experiments, as claimed by Harding, cannot be taken as accepted in general. D. V. Gogate and Duleh Singh Kothari[6] calculated the surface tension of liquid metals on the free electron model of Sommerfeld, whereas D. S. Kothari and R. C. Majumdar[7] worked out the compressibility of alkali metals, and N. K. Saha and D. S. Kothari[8] the latent heat of fusion of metals on this model. Mention may be further made of works of S. C. Roy[9] on the theory of thermo-ionic emission phenomena of Dushman and Richardson.

In the field of *radioactivity* the following works may be mentioned. The question of disintegration of radioactive substance was worked out by S. Gupta[10] according to Dirac's relativistic wave equations, using the method of Laue and Sexl. It appears that using the relativistic calculation the disintegration constant is greater than that obtained from Schrödinger equations and this increase is somewhat greater for small velocities than for large

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[1] K. C. Kar and K. K. Mukherjee, *Phil. Mag.*, **17**, 993, 1934.

[2] S. C. Kar, *Zs. f. Phys.*, **81**, 139, 1933.

[3] R. C. Majumdar, *Proc. Nat. I. Sc. Ind.*, **1**, 77, 1935.

[4] N. K. Saha, *Trans. Nat. Inst. Sci.*, **1**, 125–185, 1936; *Ind. Journ. Phys.*, **18**, 623, 1935.

[5] M. Sengupta, *Ind. Jour. Phys.*, **11**, 321, 1937.

[6] D. V. Gogate and Duleh Singh Kothari, *Phil. Mag.*, **20**, 1136, 1935.

[7] D. S. Kothari and R. C. Majumdar, *Naturwissenschaften*, **21**, 443, 1931.

[8] N. K. Saha and D. S. Kothari, *Science and Culture*, 1, 300, 1935.

[9] S. C. Roy, *Proc. Roy. Soc.*, **112**, 599, 1926.

[10] S. Gupta, *Zs. f. Phys.*, **69**, 686, 1931.

ones. In an interesting paper A. C. Banerjee [1] examined the mechanism of α-ray emission spectrum. He assumes thereby that the α-ray emission is due to change in energy level of an α-particle or any charged positive particle describing quantum orbits in the nucleus in a potential field given by

$$V = \frac{2e^2z}{} \quad 1-\frac{r_0}{r} \qquad r_0 \sim 10^{-13}\text{ cm.}$$

i.e., the nuclear radius. Solving the Schrödinger equation with this potential field he found two cases: (1) leading to negative energy levels, transition between which would correspond to rays 600 times harder than the K-spectrum of the element and is therefore only comparable with the cosmic rays. This is, therefore, incapable of explaining ordinary α-ray emission, and (2) leading to positive α-particle energies, in general agreement with experimental values observed in radioactive emission and such that the difference between the energy levels corresponds to α-rays of the right order of hardness. The theory was applied to the γ-ray spectrum of radium B, radium C, thorium C+C′ etc., nuclear quantum number being chosen to fit the observed γ-ray frequencies. Banerjee also attempted to work out the problem of scattering of α-particles by light atoms in a field similar to that suggested by Debye and Hardmeyer; numerical calculations were also given for Al and Mg. K. K. Mukherjee [2] introduced a correction term in the potential used by these authors due to the fact that the α-particle cannot approach the centre of the scattering force, whereas M. Ghose [3] extends this idea to the scattering of electrons by the atoms.

Mention may be made in this connection of the work of M. Ghose and K. C. Kar [4] who extended the theory of Born approximations, which are extensively employed in the problem of scattering phenomena, and obtained exactly the expression of Holtsmark for elastic scattering. It may also be mentioned that H. J. Bhabha [5] investigated the rôle played by showers in the absorption of cosmic radiation and from a comparison with the experimental data he calculated the effective cross-section for the production of showers at a lead nucleus.

Reference may be made to some of the interesting works carried out by H. J. Bhabha [6] on the passage of charged particles with a velocity approximately equal to that of light through

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1 A. C. Banerjee, *Phil. Mag.*, **9**, 273, 1930; **10**, 450, 1930.
2 K. K. Mukherjee, *Phys. Zs.*, **34**, 175, 1933.
3 M. Ghose, *Phil. Mag.*, **20**, 234, 1935.
4 M. Ghose and K. C. Kar, *Phil. Mag.*
5 H. J. Bhabha, *Zs. f. Phys.*, **86**, 120, 1933.
6 H. J. Bhabha, *Proc. Roy. Soc.*, A, **152**, 559, 1935; *ibid.*, **154**, 195, 1936; *Camb. Phil. Soc. Proc.*, **31**, 394, 1935.

matter. Bhabha investigated in detail the creation of electron pairs by fast charged particles. The creation of electron pairs in the collision of particles moving with relative velocity very near the velocity of light was calculated ; the effect of screening being considered. He found that the effective cross-section for the pair creation by fast proton in lead is more than a thousand times larger than the cross-section for pair production by slow protons calculated by Heitler and Nordheim. For the collision of electron of 10^8 e.V. with a lead nucleus, the cross-section is of the order of 10^{-24} cm.^{2} and is about that of the cross-section for the creation of a pair by α-ray of the same energy. Bhabha further considered the ordinary collision of an electron with a positron, and the consequent scattering is studied on the Dirac's theory of the positron. It was shown that exchange may take place between the electron we initially observe, and one of the virtual electrons in states of negative energy and that this exchange very considerably modifies the scattering. Recently Bhabha and Heitler[1] suggested a new mechanism of shower production assuming that the incident radiation is electron. They calculated from relativistic quantum mechanics the number of secondary positive and negative electrons produced by a fast primary electron with energy E, passing through a matter of thickness l. The primary electron in the field of a nucleus has a large probability of emitting a hard light quantum which then creates a pair. The pair electrons emit a quantum again which creates pair and so on. The number of secondaries increase rapidly with E_0. If an electron of 10^9 e-volts pass through a lead plate 5 cm. thickness the number of particles emerging from the plate amounts to 1,000 or more. Rosse's transition curve and Regener's absorption curve in the atmosphere can be understood. The absorption coefficient of radiation found at a depth of 100 m. of water cannot be understood on this theory if the radiation is due to primary electron.

S. M. Sulaiman[2] has, in order to explain both the wave and the particle aspects of light, recently (1934–6) put forward the theory that a light corpuscle is a binary system of two components of equal and opposite charges rotating round each other. Applying Maxwell's equations he has shown that such a system is propagated automatically with the velocity of light, and has also given physical explanation of light phenomena.

In a paper on the origin of mass in the neutron and the proton, M. N. Saha[3] has given a very simple proof of the existence of free magnetic poles, first deduced by Dirac. He has tried to prove that the neutron can be regarded as a dipole consisting of two magnetic poles of opposite sign.

[1] H. J. Bhabha and Heitler, *Proc. R.S.* (A), **159**, 432, 1937.
[2] S. M. Sulaiman, *Proc. U.P. Acad.*, **4**, 1, 1934 ; *ibid.*, **4**, 217, 1934.
[3] M. N. Saha, *Ind. Jour. Phys.*, **10**, 141, 1936.

R. C. Majumdar [1] attacked the case of motion of electrons in the ionosphere from the quantum mechanical point of view, which, according to him, is necessary as the collision is between electrons on one hand, and ions and neutral particles on the other hand. He deduced, in a rigorous way, the equation of wave propagation in a homogeneous, isothermal atmosphere. In the particular case when the collision frequency is taken to be independent of the energy of the electron, the equations are found to be identical with those given by Appleton. He showed that, provided measurements of absorption of radio waves in the ionosphere are available, one can distinguish whether collisions which take place are between electrons and ions, or between electrons and neutral particles.

XI. Wireless Research.

(a) *Propagation of Radio Waves.*

Researches on the Ionosphere were started by Prof. S. K. Mitra [2] in the University College of Science, Calcutta, in 1928. Along with his pupils, H. Rakshit, P. Syam and J. N. Bhar, he carried out a large amount of valuable measurements. of the height and density of the various layers of the ionosphere, upper and lower, and also studied their diurnal and seasonal variations. The Calcutta workers have also studied the influence of solar eclipse, meteoric showers, thunderstorms, and magnetic storms on the ionosphere.

H. Rakshit [3] participated in the programme of the Second International Polar Year (1932-33) and carried out systematically measurements of the equivalent heights of the ionospheric regions by the echo method. The observations were carried for different months of the year, and at various hours of the day, and thus the first indications of the nature of the diurnal and seasonal variation of the ionosphere of a subtropical region like that of India were obtained.

Recent meteoric observations by J. N. Bhar [4] have provided data for estimating the upper limit of the pressure existing at a height of about 250 km.

S. K. Mitra [5] and his pupils, A. C. Ghosh and B. C. Sil along with S. S. Banerjee of Benares, have also studied what may be termed the artificial ionosphere—a chamber containing ionised air under the influence of an external magnetic field. The splitting of electro-magnetic waves when propagated through an ionised medium has been clearly demonstrated by these laboratory experiments. A number of experimental anomalies regarding the variation of

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[1] R. C. Majumdar, *Indian Science Congress, Math. Phys. Section,* Abs. No. 4, 1937; *Zs. f. Phys.* (to appear shortly). *Transaction Bose Research Institute,* **11**, 1936-37.

[2] S. K. Mitra, *Proc. Nat. Ins. Sci.,* **I**, 130, 1935.

[3] H. Rakshit, *Phil. Mag.,* **18**, 675, 1934.

[4] J. N. Bhar, *Ind. Jour. Phys.,* **11**, 109, 1937.

[5] S. K. Mitra, *Nature,* **123**, 769, 1929.

dielectric constant with frequency has also been recently cleared up by S. S. Banerjee [1].

The most conspicuous contribution from Prof. Mitra's [2] laboratory has been the discovery of the D and C layers of ionization, lower than the permanent Kennelly-Heaviside layer, at heights of 55 and 30 km. respectively. This discovery was first announced in a meeting of the National Institute of Sciences of India, in August 1935, and, though first received with a certain amount of scepticism by the western investigators, has been completely confirmed by the subsequent work of Colwell and his pupils in America and Watson Watt and his collaborators in England. The discovery is of a very fundamental nature as it is not expected on the present theories, and shows the necessity of attacking the problem of ionization and absorption in the atmosphere from a new standpoint [3].

Since 1934, the study of ionosphere was carried out at Allahabad under the guidance of Prof. M. N. Saha by Dr. G. R. Toshniwal and his colleagues B. D. Pant, R. R. Bajpai, R. N. Rai and K. B. Mathur. They have collected valuable data regarding the diurnal and seasonal variation of the heights and electron densities of the various ionised strata. An important contribution from the Allahabad Laboratory is the discovery of the threefold splitting of the radio-waves by G. R. Toshniwal [4] who obtained records of reflection of the x-wave satisfying the condition $p_0^2 = p^2+pp_H$. His interpretation has been confirmed recently by Leiv Harang working at Tromso and R. Jouaust and his co-workers in France. Toshniwal has put forward a new explanation of the absorption of radio waves which has, however, been contested by J. N. Bhar [5]. Toshniwal, Pant and Bajpai [6] have also suggested an explanation for the origin of complex echoes.

R. N. Rai [7] has found an additional condition for reflection of the x-wave proceeding from the assumption that reflection takes place when group velocity becomes zero. Exactly the same results have been obtained theoretically by R. R. Bajpai [8] in a straightforward manner proceeding from altogether different conditions.

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[1] S. S. Banerjee, *Paper No. 42, Mathematics and Physics section, Indian Science Congress*, 1934.

[2] S. K. Mitra and P. Syam, *Nature*, **135**, 953, 1935.

[3] The workers on the Ionosphere are grateful to Prof. Mitra for the compilation of a report entitled 'Present state of our knowledge of the Ionosphere' published by the National Institute of Sciences of India. This compresses, within a small volume, a large amount of useful material scattered in literature.

[4] G. R. Toshniwal, *Nature*, **135**, 471, 1935.

[5] J. N. Bhar, *Science and Culture*, Nov. 1936.

[6] G. R. Toshniwal, B. D. Pant and R. R. Bajpai, *Proc. Nat. Ins. Sci.*, **3**, 337, 1937.

[7] R. N. Rai, *Proc. Nat. Ins. Sci.*, **3**, 307, 1937.

[8] R. R. Bajpai, *Nat. Acad. Sci. India*, **8**, 1937.

This new condition of reflection has cleared up the very notable and puzzling experimental result obtained a few months before by Pant and Bajpai [1] that the difference in the critical penetration frequencies for the ordinary and the extraordinary rays was on many occasions observed to be only 0·14 Mc/Sec. at Allahabad (when the electron concentration in the F-region was such that the critical penetration frequency was nearly 4 Mc/Sec.) while according to the older theories (Appleton-Hartree) this difference should have been about 0·74 Mc/Sec, a result which was also observed at times by the above workers. Bajpai and Mathur [2] have drawn group-velocity curves for different frequency and electron-concentration.

M. N. Saha and R. N. Rai [3] have worked out mathematically the reflection of the o-component of the radio wave by thin, but highly concentrated electron barriers, as for example, we get in the abnormal E-region reflexion, in M-reflexion, and in partial reflexion of the x-wave according to the three modes. They have proved that even when the condition $p^2 = \frac{4\pi Ne^2}{m}$ is fulfilled, waves can penetrate considerable thickness, about 3 km. of electron layer.

It is well known that a general explanation of the upper air ionization by the ultraviolet rays of the sun was given by Pannekoek by using a modified form of the Saha ionization formula. This work was further extended by Chapman. Saha [4] has considered the action of ultraviolet sunlight on the constituents of the Upper Atmosphere in detail, and has shown that the Pannekoek-Chapman method is not capable of explaining the observed intensity of the negative bands of nitrogen in the morning and evening flashes, and the intensification of these bands in the sunlit aurora, if we regard that the sun radiates like a blackbody at 6,000 K. He has suggested that in the ultraviolet region, the fundamental lines of H, He and other elements are emitted as emission lines with an intensity which may be about million times the intensity of the 6,000 K-blackbody background.

L. C. Verman, S. T. Char [5], and Aijaz Mohammad, at Bangalore, obtained continuous records of the equivalent height and the intensity of the received pulses some four years ago. It is unfortunate that this work has come to a standstill.

Khastgir [6] and his pupils, B. Sen Gupta and D. N. Choudhury at Dacca, have measured the height of the ionosphere by the method of signal fading.

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[1] B. D. Pant and R. R. Bajpai, *Science and Culture*, **2**, 409, 1937.
[2] R. R. Bajpai and K. B. Mathur, *Ind. Jour. Phys.*, **11**, 165, 1937.
[3] M. N. Saha and R. N. Rai, *Proc. Nat. Ins. Sci. India*, **3**, 359, 1937.
[4] M. N. Saha, *Proc. Nat. Ins. Sci. India*, **I**, 217, 1935.
[5] L. C. Verman, S. T. Char, A. Mohammad, *Proc. I.R.E.*, **22**, 906, 1934.
[6] S. R. Khastgir, B. Sen Gupta and D. N. Choudhuri, *Phil. Mag.*, **22**, 132, 1936.

Some ionospheric measurements were made at Benares by P. K. Dutt and S. S. Banerjee [1].

Signal strength measurements—absorption and determination of electric constants of the soil.

Signal strength measurements of the local transmitter have been made by H. Rakshit and K. K. Roy [2] at Calcutta working in Prof. Mitra's laboratory. From these measurements many important data such as effective height, aerial radiation and efficiency and service area of the Calcutta transmitter have been obtained. The conductivity of the soil at various places has also been deduced from these data. Signal strength measurements have also been made by K. Srinivasan [3] at Bangalore. At Dacca, Khastgir [4] and his pupils have analyzed a large number of continuous observations of 'fading' of the Calcutta V.U.C. signal. From this analysis they have been able to estimate the value of the ratio of the vertical electric forces produced by the ground wave and the downcoming wave. Khastgir [5] has also studied the ground absorption of wireless waves and in connection with his work on absorption, he, in collaboration with B. Sen Gupta, has determined the electrical constants of the Dacca soil at radio frequencies.

(*b*) *Atmospherics.*

In India the study of atmospherics was first taken up by S. N. Subba Rao [6] at the Annamalai University. His work shows that, in addition to 'fine' structure, lightning flashes have also got a 'gross' structure. He has suggested that possibly the complex nature of the electric discharge—each group consisting of several separate strokes—accounts for the divergence in the observations of lightning flashes reported by various investigators.

Important work concerning the study of the wave forms of atmospherics has been done at Madras by C. V. Rajam [7]. The chief points of his study are classification, frequency of occurrence, durations, intensities, diurnal variation and the production of noises in receivers.

(*c*) *General.*

Khastgir and A. K. Das Gupta [8] have carried out a number of experiments on crystal rectification and have made a detailed study of the effect of heat, ultraviolet light and X-rays on crystal rectifica-

[1] S. S. Banerjee and B. N. Singh, *Nature*, **137**, 583, 1936.
[2] H. Rakshit, *Phil. Mag.*, **11**, 174, 1931.
[3] K. Srinivasan, *Wireless Eng.*, **5**, 205 and 275, 1928.
[4] S. R. Khastgir and B. Sen Gupta, *Ind. Jour. Phys.*, **10**, 133, 1936.
[5] B. Sen Gupta and S. R. Khastgir, *Phil. Mag.*, **22**, 265, 1936.
[6] S. N. Subba Rao, *Nature*, **136**, 683, 1935.
[7] C. V. Rajam, *Nature*, **138**, 1064, 1936.
[8] S. R. Khastgir and A. K. Das Gupta, *Phil. Mag.*, **19**, 557, 1935.

tion. Khastgir[1] has also propounded a new theory of crystal rectification known as the 'surface theory of rectification in ionic crystals'. He claims that his theory explains certain results obtained in his laboratory which defy explanation on the basis of the existing theories of Eccles and Schottky.

A very important contribution to the radiation resistance of transmission lines from ultra high frequency as affected by bends and curves has been made by S. S. Banerjee[2] of Benares working in the laboratory of Prof. S. K. Mitra. Banerjee found that in order that such bends may not be sources of spurious radiation, the transmission lines (parallel wire) must not have any folds in the plane of the wires.

S. S. Banerjee and B. N. Singh[3] have employed short parallel wire transmission lines for the modulation of ultra-short waves of lengths 4-5 metres by high frequencies of the order of 1·5–3 megacycles per second. It has been shown that amplitude modulation free from frequency modulation is obtained when the length of the line is an integral multiple of a quarter of the carrier wavelength. The effects of the carrier wave and side bands, adequately separated have been studied with a modified Lecher wire system.

(*d*) *Need of a Radio Research Board in India.*

The type of researches on Radio and Ionosphere which are being carried on in India by a few bands of enthusiastic workers is conducted in other countries under the auspices of some central organized body. On account of the national importance of these subjects most of the countries have formed organizations known as Radio Research Boards. The function of these bodies is to co-ordinate the works carried out in the universities, in the various research institutions and in the government departments and also to make a planned attack on the unsolved problems. England, Australia, Canada, Japan and the United States of America all have Radio Research Boards or bodies similar to it. Unfortunately, the Government of India has not yet been persuaded to the advisability of setting up such a board.

XII. X-Rays.

The earliest worker on X-rays in India is Prof. C. V. Raman[4], who started it as a side issue of his work on the diffraction of light by matter ; he was led to believe that systematic study of diffraction effects observed with ordinary light and with X-rays would result in significant advances in our knowledge of the phenomena. His

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1 S. R. Khastgir, *Ind. Jour. Phys.*, **9**, 347, 1935.
2 S. S. Banerjee, *Phil. Mag.*, **19**, 787, 1935.
3 S. S. Banerjee and B. N. Singh, *Nature*, **138**, 890, 1936.
4 C. V. Raman, *Phil. Mag.*, **45**, 113, 1923.

attention was first drawn to the haloes or rings which are obtained as a result of the diffraction of X-rays through liquids. Raman and Ramanathan[1] attempted to explain the origin of these rings on the supposition that the arrangement of molecules in liquids is not in perfect chaos, but possesses certain amount of orderliness. They applied Einstein-Smoluchowski's theory of density fluctuations to this interesting problem, and deduced a theory which fairly accounts for the principal diffraction haloes. Experimental studies in this direction were made by C. M. Sogani[2] who examined several liquids with reference to their molar arrangement, and for finding out the effect of compressibility of liquids on X-rays haloes. Ramsubramanyam and V. I. Vaidyanathan[3] studied the effect of high temperature on X-ray haloes in liquids and amorphous solids and the results obtained by them could be quantitatively understood from Raman and Ramanathan's theory.

P. Krishnamurty[4] carried out extensive investigations with a large number of organic liquids, liquid mixtures, and solutions of crystalloids. He extended his investigations not only to various forms of amorphous carbon, colloidal solutions of dextrin, gelatin, sodium oleate, etc. but also to aqueous solutions of liquids, such as phenol, trimethyl carbonol, piperidine, glycerine, ethyl alcohol, lactic acid, etc. The results of his investigations could now be easily correlated and understood from the cybotactics hypothesis of Stewart. Mahadevan[5] also examined the important varieties of coal, vitrain and deurain. Interesting results were also obtained by P. Mukherji[6] on the internal scattering of various forms of carbon, placed under different conditions. K. Banerji[7] also studied the X-rays diffraction in the liquid alloys of sodium and potassium.

The discrepancy observed from the measurements of magnetic susceptibilities of naphthalene and anthracene against the structure tentatively assumed by Sir William Bragg led K. Banerji[8] to re-investigate the atomic arrangements in the crystal of these two substances. He found that the molecules are inclined to the cell faces, the correct position being obtained by first placing them along the *bc* plane and then by two successive rotations about the *b* and *c* axes. The rotations about the *b*-axis for the two molecules in the unit cell are equal and opposite while about *c* they are in the same direction in conformity with the space group $C_{2h}{}^5$. All the

[1] C. V. Raman and K. R. Ramanathan, *Proc. Ind. Assoc. Cult. Sci.*, **8**, 127, 1923.

[2] C. M. Sogani, *Ind. Jour. Phys.*, **2**, 97, 377, 1928.

[3] Ramsubramanyam, *Ind. Jour. Phys.*, **3**, 137, 1928; V. Vaidyanathan, *Ind. Jour. Phys.*, **3**, 931, 1929.

[4] P. Krishnamurti, *Ind. Jour. Phys.*, **3**, 307, 1929; **4**, 99, 1929; **5**, 473, 1930.

[5] Mahadevan, *Ind. Jour. Phys.*, **5**, 525, 1930.

[6] P. Mukherji, *Zeits. f. Phys.*, **88**, 247, 1934.

[7] K. Banerji, *Ind. Jour. Phys.*, **3**, 399, 1929; **4**, 541, 1930.

[8] K. Banerji, *Proc. Roy. Soc.*, **141**, 188, 1933.

benzene rings in the same molecule are in the same plane and the rings are practically regular hexagons.

K. Banerji and his students[1] at Dacca analyzed a large number of organic crystals such as paradinitro-benzene, benzamide, acenaphthene, benzil, hydrazobenzene, benzophenone and completed the determination of the structures of these compounds. Assuming the structure of the benzene nucleus to remain intact in these molecules, they have been able to draw definite conclusion regarding the structure of these molecules. J. Dhar[2] has also made a systematic study of the structure of diphenyl, dibenzyl and *p*-dihalogen derivatives of diphenyl. He has shown that in diphenyl, the benzene ring is a flat regular hexagon and the diphenyl molecule strictly conforms to linearly extended structure with two coplanar benzene rings. Prof. Mata Prasad[3] and his students at Bombay (Royal College of Science) have analysed a large number of crystals, the analysis being complete in some cases and in other cases leading only to the determination of space groups. Complete analysis has been made of the crystals of azobenzene, stilbene and totane and the space groups of the crystals of copper formate, acenaphthene, hydrazobenzene, *m*-azotoluene and *p*-azotoluene have been determined and the symmetry of the molecules has been found. Similar analysis made by them in the case of *p*-nitro biphenyl, *p*-amino azobenzene, anthranilic acid, diphenyl nitrosamine and *o*-azotoluene has led to the conclusion that these molecules are asymmetric. Prof. K. Prasad[4] and his students at Patna have set up an X-ray laboratory, where investigations on X-ray spectrography, soft X-rays and crystal structure are being carried on. Their works cover a wide field of problems, such as examination of fish scales and tortoise shell, investigation of X-ray haloes of primary and isomeric alcohol from methyl to amyl, X-ray and photographic reversal, etc. In the field of X-ray spectrography, they have investigated the effects of intense cooling on the intensity of the L-lines emitted by copper and iron. Mass absorption coefficient of aluminium has been measured by them in the region of soft X-rays from 7A to 25A.

K. C. Majumdar[5] at Duane's laboratory in the Harvard University carried on investigations in the K series spectra of Tungsten, on the absorption of short X-rays by lithium. Khastgir

[1] K. Banerji, *Phil. Mag.*, **18**, 1004, 1934; *Ind. Jour. Phys.*, **9**, 287, 1935; **11**, 21, 1937.

[2] J. Dhar, *Ind. Jour. Phys.*, **7**, 43, 1932; **9**, 1, 1934.

[3] Mata Prasad, *Phil. Mag.*, **10**, 306, 1930; **13**, 600, 1932; **16**, 639, 1933; *Ind. Jour. Phys.*, **6**, 41, 1931; **8**, 77, 1933; **9**, 239, 319, 1935; *Proc. Roy. Soc.*, **154**, 187, 1936.

[4] K. Prasad, *Ind. Jour. Phys.*, **10**, 267, 1936; *Zeits. f. Phys.*, **102**, 259, 1936; *Phil. Mag.*, **21**, 869, 1936.

[5] K. C. Majumdar, *Proc. Nat. Acad. Sci.*, 8, 45, 1922; *Zeits. f. Phys.*, **46**, 449, 1927.

and Sen Gupta[1] were for long devoted to the J-radiation of Barkla. Dasannacharya[2] made some interesting experimental observations on the polarization of X-rays emitted from thin aluminium anticathodes and also on the polarization of the continuous X-rays from single electron impacts. He showed that percentage of polarization increases exponentially with the decrease in thickness of the target and from extrapolation he concluded that complete polarization could be obtained for all voltages when the thickness of the aluminium target is 6×10^{-6} cm. G. B. Deodhar (at Siegbahn's laboratory at Uppsala, Sweden) performed some experiments[3] on the fine structure of the K-absorption limit of silicon oxide and carried on investigations on the X-ray non-diagram lines both for K and L series and attempted to explain the origin of most of these lines on the assumption that they arise from transitions in multiply-ionised atoms. He has further shown that pairs exist in non-diagram lines, which show approximately constant frequency difference.

B. B. Ray[4] (at Siegbahn's Laboratory, Uppsala) has made some interesting studies on the irregularity of the K doublets in the elements of the lower atomic number. His extended investigation on the irregularity of the L-doublets for a large number of elements, led him to conclude that irregularities are only peculiar to transitional elements. He further observed that not only does the doublet difference in the lower element depend on the chemical state of the compound but also in the case of sulphur, the wavelengths of the K lines change with different chemical constitution. Ray also made some observations on the identity of some of the lines in the L series of Tungsten by photographic method. He is one of those who suggested the possibility of the double transition in X-rays and from the analogy with the optical spectra he attempted to explain the origin of the spark lines in X-rays. Ray[5] has measured the K-absorption limit of elements from 37 Rb to 50 Sn and from the measurements of the secondary absorption edges in the L series of caesium and barium, he has drawn attention to the fact that Krōnig's theory is not sufficient to explain the peculiarities of these edges and Siegbahn's contention for the selection principle for absorption edges may solve the difficulty. Raman[6] has

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1 S. Khastgir and Sengupta, *Phil. Mag.*, **49**, 251, 1935; **50**, 1115, 1925; **2**, 642, 1926; **4**, 735, 1927; **14**, 99, 1932.

2 B. Dasannacharya, *Phy. Rev.*, **36**, 1675, 1930.

3 G. B. Deodhar, *Proc. Roy. Soc.*, **131**, 476, 1931.

4 B. B. Ray, *Phil. Mag.*, **48**, 707, 1924; **49**, 168, 1925; **50**, 505, 1925; **8**, 772, 1929; *Zeits. f. Phys.*, **53**, 646, 1929; **54**, 534, 1929; **55**, 119, 1929; *Ind. Jour. Phys.*, **3**, 477, 1929; *Arkiv f. Mat. Astrom., och Fysik*, **18**, 19, 1924.

5 B. B. Ray, *Zeits. f. Phys.*, **88**, 218, 1934; *Arkiv f. Mat. Astrom., och Fysik*, **13**, 1, 1934.

6 C. V. Raman, *Ind. Jour. Phys.*, **3**, 357, 1929; *Proc. Roy. Soc.*, **119**, 526, 1928.

calculated the intensity of X-rays scattered by a group of electrons moving independently of each other about atomic nucleus and has derived a theoretical expression from classical mechanics, which contains both the coherent and incoherent radiation and the latter can be interpreted as arising from the Compton effect.

M. N. Saha and R. K. Sharma[1] have shown that the screening constant for the K and L-levels varies from element to element and foreshadowed an empirical method for calculating them. They have shown that Sommerfeld's method of calculating the screening constants is not quite logical. Saha and J. B. Mukherjee[2] have calculated the probability of inter-transition in the L-shells and have suggested that the non-appearance of these inter-transitional lines in many elements might be just due to the fact that the energy of the inter-transition is just greater than some of the outer M-shells and so they are internally absorbed. Coster and Krönig[3] have further extended the suggestion.

B. Ray[4] at one time believed to have observed radiations modified by the scattering of X-rays by bound electrons but his work was not generally supported by other investigators. But recently Sommerfeld has shown the possibility of the existence of such modified radiation purely from theoretical consideration. H. Dey[5] has made observations on the partial polarization of continuous X-rays emitted from thin aluminium anticathode by counting the photoelectrons emitted in different directions using a Wilson Cloud Chamber and the results are fairly in accord with those observed by Duane and others, who studied the same phenomena by other methods.

S. Ramachandra Rao[6] measured the critical potential in the soft X-ray region from single crystal face of Nickel and also some polycrystalline metal faces by electron bombardment method. The same was followed by G. Bandopadhya[7], who made some interesting observations on the photo-electric effect on X-rays. H. Singh also followed the same method for the measurement of the critical potential from Copper and Iron. S. R. Das and K. Ray[8] studied the important allotropes of sulphur, and came to the conclusion that plastic sulphur is the only amorphous variety of sulphur, and the rest are crystalline. Excepting white sulphur, all but the monoclinic variety have the space-group V. White sulphur also transforms to this form at 88°C. They further noticed that the transition from rhombic to monoclinic form

1 M. N. Saha and R. S. Sharma, *Bull. U.P. Aca. Sci.*, **1**, 119, 1932.
2 M. N. Saha and J. B. Mukherjee, *Nature*, **133**, 377, 1934.
3 Coster and Krönig, *Physica*, **2**, 13, 1935 ; **3**, 282, 1936.
4 B. B. Ray, *Zeits. f. Phys.*, **66**, 261, 1930.
5 H. Dey, *Ind. Jour. Phys.*, **9**, 507, 1935.
6 S. Ramachandra Rao, *Proc. Roy. Soc.*, **128**, 41, 1930.
7 G. Bandopadhya, *Proc. Roy. Soc.*, **120**, 46, 1928.
8 S. R. Das and K. Ray, *Sci. and Cult.*, **1**, 784, 1936 ; **2**, 108, 652, 1936-37.

starts above 50°C. and is always accompanied by growth of the crystal size and distortion of lattice planes.

Work on the constitution of jute and other fibres by X-ray methods have been started by B. B. Ray [1] and his pupils.

Laue photographs of iridescent crystals of potassium chlorate have been studied by S. C. Sarkar [2], and it has been shown that the iridescence is due to the presence of a large number of twinned strata almost parallel to each other inside the crystal.

XIII. Meteorology [3].

A review of the progress of meteorology in India during the last twenty-five years may appropriately begin with a reference to the valuable pioneer work which had been done by Mr. H. F. Blanford and Sir John Eliot during the last quarter of the nineteenth century. Even to-day, Blanford's 'Indian Meteorologist's Vade-Mecum' and 'The Climate of India, Burma and Ceylon' and Eliot's 'Hand Book of Cyclonic Storms in the Bay of Bengal' and 'Climatological Atlas' form the foundation of our knowledge of weather and climate in India.

(a) *Seasonal Forecasts.*

A meteorological service aims to predict the day to day changes in weather and to issue timely warnings against high winds, heavy rainfall, floods, cyclonic storms, etc., to various interests over land and out at sea. In India the forecasting of seasonal rainfall has also engaged the attention of the meteorologists since the time of Blanford, and in this matter, India has given the lead to other countries.

Seasonal forecasts are of importance to the predominantly agricultural population of this country and incidentally also to Government in estimating financial prospects. This was recognized as early as 1884 when Blanford began issuing monsoon forecasts which were based mainly upon certain previous weather conditions in India. Eliot improved upon this method by considering the possible influence of extra-Indian factors, e.g., pressure at Seychelles, Australia, etc. Both Blanford and Eliot, however, depended much on intuition.

Sir Gilbert Walker [4], who succeeded Eliot as Director-General of Observatories, introduced in 1906-07 the correlation-coefficient and

1 B. B. Ray, *Sci. and. Cult.*, **2**, 653, 1937.

2 S. C. Sarkar, *Ind. Jour. Phys.*, **5**, 337, 1930.

3 The writer (Dr. A. K. Das) is indebted to Dr. C. W. B. Normand, Director-General of Observatories in India, for advice in the preparation of this article.

4 G. Walker, *Mem. Ind. Met. Dept.*, **21**, 13, 1914; *ibid.*, **23**, 22, 1922; *ibid.*, **24**, 333, 1924.

the multiple regression equation in his monsoon forecasts, thus applying, for the first time, numerical methods to the preparation of seasonal weather forecasts and eliminating the personal factor. By the application of the methods of correlation-coefficients, Walker discovered certain important relationships between weather in distant parts of the earth. The main conclusion reached in his 'World Weather' investigations is that there are three big swayings or oscillations :—

(*a*) The North Atlantic oscillation between the Azores and Iceland,
(*b*) The North Pacific oscillation between the high pressure belt and the winter depression near the Aleutian Islands ; and
(*c*) The Southern oscillation, mainly between the South Pacific and the land areas round the Indian Seas.

The method of correlation-coefficients has ever since been employed in monsoon forecasting in India and considerable improvements have been made in the method by introducing Walker's significance test for selecting correlated factors.

A still further improvement is that introduced by Dr. C. W. B. Normand [1], the present Director-General, and named by him the 'Performance Test of Significance'. Whereas Walker's method aims at eliminating personal bias once the forecasting factors have been chosen, the Performance Test provides a means for surmounting personal bias in the ultimate choice of factors. The application of this idea in practice would be as follows : Suppose we want to forecast rainfall in a particular area. We correlate the rainfall in that area with a number of other factors using part of the available data. We have now to choose, say, four or five suitable factors and form a multiple regression equation. This choice of factors, depending as it does on individual judgments, can be a serious drawback to the usefulness of the forecasting formula. The Performance Test consists in correlating the actual 'unused' data with the corresponding data calculated or 'predicted' from the forecasting formula. The correlation-coefficient should be positive and, if it is significant, the full data may be used for obtaining a more accurate forecasting formula.

Dr. S. R. Savur [2] has shown that the Performance Test can be applied to various other statistical problems and is likely to be an important aid in statistical investigations in general.

Daily Weather Forecasting

(*a*) *Utilization of Upper Air data.*—Prior to 1914 daily weather prediction in India was made mainly from surface data. Since then upper air data from a slowly increasing number of stations have come to

1 C. W. B. Normand, *Q.J.R. Met. Soc.*, 58, 3, 1932.
2 S. R. Savur, *Ind. Jour. Physics*, 8, 27, 1932.

the forecaster's aid. The pioneer in upper air organization in India was J. H. Field. The work initiated by him is being continued by G. Chatterji. The upper air data used for daily weather work are the velocity and direction of wind at various heights above the ground telegraphed from a net-work of 38 stations. More detailed information such as pressure, temperature and humidity at various levels would have been very valuable, but there are practical difficulties in obtaining this information for the use of the forecaster. It is gratifying to note, however, that G. Chatterji[1] has invented temperature indicators (based on the principle of the bimetallic thermometer) for use in the first few kilometres above ground. He has also designed a hygrograph for obtaining continuous records of dry and wet bulb temperatures in the lower levels of the upper atmosphere and an improved type of Dines Meteorograph which is particularly suitable, on account of its enlarged scale, for sounding the lower layers of the atmosphere. Another set of very inexpensive instruments has been designed by A. K. Das[2] for obtaining quickly the values of temperature and pressure and the heights of inversions in the lower levels of the free atmosphere. These instruments are based on the principle of the air thermometer so that any one with a reasonable experience of glass-blowing can make them with little trouble. The use of aeroplanes for obtaining direct information of conditions in the first few miles of the atmosphere is at present confined, in India, to a few R.A.F. stations in North-West India.

(*b*) *Frontal Analysis*.—A powerful method that has come to the forecaster's aid is the analysis of air masses first introduced by V. Bjerknes. It is now well recognized that weather is caused by interaction between different types of air masses. Several ways of recognizing air masses have been suggested, but a very useful, yet simple, method is the use of the 'Wet-bulb potential temperature' first put forward by Normand[3]. The importance of this method is at once recognized when it is seen that the wet-bulb potential temperature 'has a definite meaning as a heat function, has an intimate relation with adiabatic process in general, and provides us with a measure of the entropy of atmospheric air', as shown by Normand. The invariance of the wet-bulb potential temperature has been the guiding factor in all the work on air mass analysis that has been recently done in India. Dr. Normand[4] also identified wet-bulb temperatures with the saturated adiabats that appear on the well-known adiabatic diagrams of Hertz and Neuhoff, and later in 1931 showed how wet-bulb curves (or 'Estergrams') entered on such diagrams can, in conjunction with dry bulb curves

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[1] G. Chatterji, *Gerl. Beitr. Z. Geoph.*, **34**, 252, 1931.

[2] A. K. Das, *Gerl. Beitr. Z. Geoph.*, **36**, 1, 1932 ; *ibid.*, **36**, 4, 1932 ; *ibid.*, **37**, 224, 1932.

[3] C. W. B. Normand, *Memoirs Ind. Met. Dept.*, **23**, 1, 1921.

[4] C. W. B. Normand, *Nature*, **128**, 583, 1931.

(or 'T-ϕ diograms') be used for the rapid classification of atmospheric layers for stability or latent instability. An account of the method is to be found in a Memoir by Mr. V. V. Sohoni and Miss Paranjpe [1], who have classified many T-ϕ diograms by this method and correlated subsequent weather with the degree of stability or latent instability evinced by the soundings.

(b) *Investigations of the Upper Air.*

The technique of pilot balloon observations and sounding work and the conclusions that could be drawn from the data collected up to the end of 1919 was elaborated in a series of memoirs by J. H. Field and W. A. Harwood [2] entitled 'The Free Atmosphere in India'.

K. R. Ramanathan [3] who made a general study of the soundings of the free atmosphere both in India and other countries, gave, for the first time, a concrete picture of the distribution of temperature up to 25 kilometres over the northern hemisphere during summer and winter. Some of his main conclusions are quoted below :—

> 'The stratosphere is not isothermal over any particular place, but above a certain level there is a tendency for the temperature to increase with height.
>
> The coldest air over the earth, of temperature about 185°A (−88°C) lies at a height of some 17 geodynamic kilometres over the equator in the form of a flat ring surrounded by rings of warm air.'

The observations in the upper air both as regards soundings and wind measurements were made at Poona, Hyderabad and Madras under the direction of the Upper Air Section at Poona, with materials supplied by the Upper Air Observatory at Agra, which under the able guidance of Mr. G. Chatterji developed the necessary technique. These observations together with those made by G. Chatterji and his co-workers at Agra have been analyzed and discussed by G. Chatterji, N. K. Sur, K. R. Ramanathan and their collaborators in a number of papers [4]. It is not possible to give an account of the many results obtained from all these investigations within the limited space of this article, but we will mention some of the important points brought out by these researches. One is that the tropopause or

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1 V. V. Sohoni and Paranjpe, *Memoirs Ind. Met. Dept.*, **26**, 131, 1937.

2 J. H. Field and W. A. Harwood, *Memoirs Ind. Met. Dept.*, **24**, Parts 5 and 6, 1921–23.

3 K. R. Ramanathan, *Memoirs Ind. Met. Dept.*, **25**, 163, 1930.

4 G. Chatterji and N. K. Sur, *Gerl. Beitr. Z. Geoph.*, **25**, 266, 1930; Ramnathan and Ramakrishnan, *Memoirs Ind. Met. Dept.*, **25**, 51, 1934; H. C. Banerjee and Ramanathan, *Ind. Met. Dept. Sc. Notes*, **3**, 21, 1930.

the transition layer between the troposphere and the stratosphere over Northern India occurs at a height of 14–18 kilometres. But there are fluctuations in the height in the different seasons, the mean height being 16·5 gkm. (temperature 194·5°K.) during the period middle of May to end of October and 14·9 gkm. (temperature 203·5°K). during the rest of the year. It is also remarkable that the temperature of the base of the stratosphere is higher in the colder months than in the hotter ones. Another striking fact is that the monsoon season (July-August) is the hottest of all the seasons up to nearly 14 gkm.

Finally it may be mentioned that upper air studies in India have led to a substantial modification of the picture of the general circulation of the atmosphere as presented by Teisserenc de Bort and Hildebrandsson.

(c) *Investigations on structure and movements of tropical storms, depressions, etc., in the Indian Seas.*

A considerable amount of research work has been done by meteorologists in India on the nature of the major weather phenomena, such as storms or depressions originating in the Indian Seas, thunderstorms of land origin, winter depressions which move from the west over Persia and Northern India. It has been well known from the time of Eliot (*vide* Eliot's *Cyclone Memoirs*, Parts I–V) that the outer storm areas of cyclones of the Indian Seas do not possess a symmetrical structure contrary to what was generally believed to be the case with tropical cyclones. Recently, however, B. N. Desai and S. Basu [1] have brought forward clear evidence in favour of non-symmetrical structure in the inner storm area of five Indian cyclones. An important point which emerges from Desai and Basu's investigation is that the calm centre or 'eye' of an Indian cyclone does not coincide with the lowest pressure, nor is the strength of winds in the inner hurricane zone symmetrical with respect to the centre. This conclusion, though not completely invalidating the usual theory of the formation of the calm centre according to which the central calm is due to the complete compensation of the pressure gradient by the centrifugal force acting on the rapidly rotating air mass, throws considerable doubt on the validity of this theory. It is well known that the Indian cyclonic storms form on a diffuse boundary between two air currents one of which is essentially of oceanic and the other of land origin. Several attempts have been made recently to investigate the structure of individual cyclones by applying the methods of Norwegian meteorologists for the extra-tropical cyclones. S. C. Roy and

[1] B. N. Desai and S. Basu, *Gerl. Beitr. Z. Geoph.*, **40**, 1, 1933; Basu and Desai, *ibid.*, **42**, 353, 1934.

A. K. Roy[1] showed, for the first time, by analyzing a number of typical Indian cyclones that there is a close analogy between the structure of the Indian cyclone and that of the extra-tropical cyclone. In fact they showed that in a fully developed Indian cyclone, there are two clear fronts similar to the warm and cold fronts of extra-tropical depressions, and that the severity of a cyclone is greatest in the pre-monsoon and post-monsoon seasons when the two constituent air masses are most strongly contrasted in their properties. The later investigations of Ramanathan[2], Sobhag Mal and B. N. Desai[3] and N. K. Sur[4] on individual cyclones have also brought forward a certain amount of evidence pointing to the existence of fronts in Indian cyclones. In some recent investigations an attempt has been made to show, by the method of air mass analysis, that there occur in the atmosphere in India surfaces of discontinuity of the inclined or 'front' type even in the absence of marked storm conditions. N. K. Sur[5] has shown by analyzing a few typical weather situations that occasionally a wedge of dry north-westerly continental air extends between the south-westerly winds from the Arabian Sea and the easterly winds of the monsoon traversing the Gangetic valley and gives rise to typical fronts with characteristic rainfall over the western United Provinces and adjacent parts.

In a recent memoir V. Doraiswami Iyer[6] has shown that an appreciable number of the residual lows from the typhoons of the Pacific Ocean and the China Sea, which strike the coast of Indo-China or South China during the period July to November, travel across the intervening hilly country and enter the Indian area. Many of these, which cross over in the months of September to November, develop into storms or well-marked depressions, those that develop into storms in the Indian Seas being of small extent.

Although our knowledge of the structure of the Indian cyclones has considerably improved in recent times, the directions of movements of storms in the Indian Seas are still not clearly understood. It may be that the track of a cyclone depends, as Harwood concluded from a statistical study, upon the wind directions at the cirrus level, but it would seem that the inclination of the spatial axis of a cyclone ought to give a better indication of the direction of travel. The winter depressions, which move into India from the west across Persia and Baluchistan were studied by B. N. Banerji[7] who showed that they present practically the same character-

1 S. C. Roy and A. K. Roy, *Beitr. Z. Ph. fr. Atm.*, **16**, 224, 1930.
2 K. R. Ramanathan, *Memoirs Ind. Met. Dept.*, **26**, 79, 1936; Ramanathan and Ramakrishnan, *ibid.*, **26**, 13, 1933.
3 S. Mal and B. N. Desai, *Ind. Met. Dept. Sc. Notes*, **4**, 87, 1931.
4 N. K. Sur, *Ind. Met. Dept. Sc. Notes*, **6**, 113, 1935.
5 N. K. Sur, *Memoirs Ind. Met. Dept.*, **26**, 37, 1933.
6 V. Doraiswami Iyer, *Memoirs Ind. Met. Dept.*, **26**, 93, 1936.
7 B. N. Banerji, 'Meteorology of the Persian Gulf and Mekran', Central Publication Branch (Govt. of India), 1931.

istics as the occluded depressions of the extra-tropical regions. Although the rainfall associated with these depressions is of considerable importance to agriculturists in north-west India, they do not in themselves present any particularly unintelligible feature which would require a special study. But there is an important type of weather phenomenon which appears in some way to be closely connected with these western depressions, namely, the series of dust or thunderstorms that occur in Northern India particularly in Bengal, Bihar, and the United Provinces during the transition seasons immediately before and after the proper winter months. These thunderstorms or 'norwesters' often occur well in front of an advancing western depression and in some parts of the country, especially in Bengal, cause violent squalls of a destructiveness, sometimes surpassing that of the severe cyclones of the Bay of Bengal. The origin and mode of occurrence of 'norwesters' have been investigated by V. V. Sohoni[1], S. N. Sen[2] and A. K. Das[3]. The effect of over-running of the damp and warm air mass over Bengal by potentially colder air above has been considered by Sohoni. The same process has been invoked by B. N. Desai[4] and by S. P. Venkateswaran[5] to explain the thunderstorms of Poona and the Peninsula. Sen however concludes from his studies on the norwesters of Bengal that these thunderstorms are caused by the undercutting of the warm moist air from the Bay by a colder and drier sample of air, which rushes down the river valleys from the eastern Himalayas. The propagation of norwester squalls has been compared by A. K. Das to the movement of cold waves in Europe and America. Assuming that the cold air moves as in W. Schmidt's laboratory experiments not as a thin-tripped wedge but as a more or less thick 'Squall-head', A. K. Das has theoretically calculated the squall-velocities for a large number of norwesters recorded at the Alipore Observatory. By this quantitative method he has shown for the first time that there is a good agreement between the theoretically calculated squall-velocities and the wind-velocities recorded by anemographs during the norwesters of Bengal; it has also been shown that the principal features of norwesters including the occasional formation of tornadoes in Bengal can be explained satisfactorily on the basis of this mechanism.

A detailed study of a few thunderstorms at Colaba led S. K. Banerji[6] to uphold the view first advanced by G. C. Simpson,

[1] V. V. Sohoni, *Ind. Met. Dept. Sc. Notes*, **4**, 19, 1931.

[2] S. N. Sen, *Nature*, **127**, 128, 1931.

[3] A. K. Das, *Gerl. Beitr. Z. Geoph.*, **39**, 144, 1933; *Current Science*, **1**, 386, 1933; *Ibid.*, **2**, 418, 1934.

[4] B. N. Desai, *Ind. Met. Dept. Sc. Notes*, **3**, 89, 1931.

[5] S. P. Venkateswaran, *Ind. Met. Dept. Sc. Notes*, **5**, 63, 1933.

[6] S. K. Banerji, *Q.J.R. Met. Soc.*, **56**, 305, 1930; *Phil. Trans. Roy. Soc.*, **231**, 1, 1933.

viz., that the electricity in thunderstorms originates from the breaking of rain drops in clouds by ascending air.

(d) Radiative and Convective processes in the Atmosphere.

The problems of radiation and turbulence in the atmosphere have received a good deal of attention from meteorologists in India during the last few years, and a number of experimental as well as theoretical investigations have been carried out. In a suggestive paper K. R. Ramanathan [1] has examined the effect of radiation on the equilibrium of the higher layers of the troposphere by employing the method used by Simpson in his famous papers on Atmospheric Radiation. It is a well-known fact that the tropical tropopause is much higher and colder than the tropopause over the middle latitudes, but this fact has not yet received a thoroughly satisfactory explanation. Ramanathan has arrived at the conclusion that over the tropics there should be a region of active convection between about 8 and 12 km. and weaker convection for two or three km. further above, both during the day and the night. Now, since in the lower levels of the troposphere up to about 8 km. the potential temperature and the moisture content are higher over the tropical regions than over the temperate zones it follows that a larger quantity of moisture can be pushed up by convection to levels of lower temperature over the tropics and consequently the level of radiative equilibrium or the tropopause should be higher and colder over the tropical regions than over the temperate latitudes. Sobhag Mal, S. Basu and B. N. Desai [2] have studied the formation of inversions of lapse-rate in the Upper Atmosphere in anticyclonic weather due to radiation from humidity and haze boundaries.

Problems connected with heat (water-vapour) radiation from the night sky have received considerable attention from K. R. Ramanathan, L. A. Ramdas and their co-workers [3]. It is found that there is a decrease in the radiation during the night due to the fall of temperature in the lower layers of the atmosphere. Radiative equilibrium is attained with near layers for regions of the spectrum for which water-vapour has high absorption and with distant layers for regions of the spectrum with low absorption by water-vapour.

In a theoretical paper (1925) on the depth of Earthquake Foci, S. K. Banerji [4] pointed out for the first time that in the seismo-

[1] K. R. Ramanathan, *Beitr. Z. Ph. fr. Atm.*, **18**, 196, 1932.

[2] S. Mal, S. Basu and B. N. Desai, *Beitr. Z. Ph. fr. Atm.*, **20**, 56, 1932.

[3] K. R. Ramanathan and L. A. Ramdas, *Proc. Ind. Acad. Sc.*, **1**, 822, 1935; K. R. Ramanathan and B. N. Desai, *Gerl. Beitr. Z. Geoph.*, **35**, 68, 1932; S. L. Malurkar, *Gerl. Beitr. Z. Geoph.*, **37**, 410, 1932; P. K. Raman, *Proc. Ind. Acad. Sc.*, **1**, 815, 1935.

[4] S. K. Banerji, *Phil. Mag.*, **49**, 65, 1925.

grams of earthquakes with deep foci, the long waves would be inconspicuous.

The distribution of temperature in the lowest levels of the troposphere up to about 200 metres above ground has been examined by Barkat Ali [1], who has shown that in Northern India the vertical distribution of temperature as well as the structure of the wind is more or less in accord with G. I. Taylor and W. Schmidt's theories of turbulence in the atmosphere. Another problem usually not considered in theories of large-scale eddy motion has been studied both experimentally and theoretically by S. L. Malurkar and L. A. Ramdas [2], namely, the question of the vertical gradient of temperature in the layer of 10 cr 15 cm. next to the ground heated by intense solar radiation in India. Malurkar and Ramdas have experimentally determined the temperature lapse-rate in the surface layer to be 1 or 2°C. per centimetre and have also given a mathematical explanation of the observed lapse-rates taking into consideration the balance between the heat received by conduction or convection process and the net loss of heat by radiation process. It is, however, extremely difficult to attain a satisfactory degree of accuracy in such measurements. L. A. Ramdas and Paranjpe [3] have attempted to obtain greater precision in the measurement of lapse-rate very close to a hot surface by the introduction of interferometric methods. Measurements of (*a*) the various factors controlling the disposal of the radiation from the sun and the sunlit sky by processes taking place near the surface of the ground, and (*b*) the factors concerned with the 'moisture balance' at the ground, have been made by Ramdas and co-workers.

Various other investigations dealing with other atmospheric problems some of which fall on the borderland of geophysics and astrophysics have been carried out by Indian meteorologists. Particularly noteworthy are the works of Simpson and S. K. Banerji [4] on atmospheric electricity and of S. K. Banerji [5] on the application of microseismic records to the determination of cyclone centres. Mention should be made also of the work of K. R. Ramanathan [6] on the observations of the spectrum of the night sky, of A. K. Das [7] on the theory of the emission of the forbidden OI lines by the night sky and of the cause of the high

[1] Barkat Ali, *Memoirs Ind. Met. Dept.*, **25**, 195, 1930; *Q.J.R. Met. Soc.*, **58**, 285, 1932.

[2] S. L. Malurkar and L. A. Ramdas, *Ind. Jour. Phys.*, **6**, 495, 1932; Ramdas and Malurkar, *ibid.*, **7**, 1, 1932.

[3] L. A. Ramdas and Paranjpe, *Current Science*, **4**, 642, 1936; M. K. Paranjpe, *Proc. Ind. Acad. Sc.*, **4**, 639, 1935.

[4] S. K. Banerji, *vide* ref. 6 on p. 738.

[5] S. K. Banerji, *Phil. Trans. Roy. Soc.*, **229**, 287, 1930.

[6] K. R. Ramanathan, *Ind. Jour. Phys.*, **7**, 405, 1932.

[7] A. K. Das, *Gerl. Beitr. Z. Geoph.*, **47**, 136, 1936; *ibid.*, **49**, 241, 1937.

temperature of the earth's outer atmosphere, of S. K. Pramanik[1] on Lunar atmospheric tides, of S. R. Savur[2] on some points in statistical theory and of J. M. Sil[3] on the measurement of the electric gradient in the atmosphere during dust storms at Poona. There is also the programme in agricultural meteorology recently begun by L. A. Ramdas[4] and his collaborators, who have already collected a substantial amount of meteorological data which should prove valuable for agriculture in India.

In concluding this brief review reference may be made to the important line of research on the ionosphere which is being conducted by S. K. Mitra at Calcutta and M. N. Saha at Allahabad. The recent observations on atmospherics and atmospheric electricity at Bangalore and the investigations in meteorological optics carried out by B. B. Ray[5] at Calcutta are also worthy of mention.

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1 S. K. Pramanik, *Memoirs Ind. Met. Dept.*, **25**, 279, 1931; S. K. Pramanik, S. C. Chatterjee and P. P. Joshi, *Ind. Met. Dept. Sc. Notes*, **4**, 1, 1931.

2 S. R. Savur, *Ind. Jour. Phys.*, **6**, 527, 1931 ; *Ind. Met. Dept. Sc. Notes*, **4**, 153, 1932 ; *Proc. Ind. Acad. Sc.*, **2**, 336, 1935.

3 J. M. Sil, *Q.J.R. Met. Soc.*, **59**, 23, 1933.

4 L. A. Ramdas, *Proc. Nat. Inst. India*, **2**, 131, 1936 ; Ramdas and Katti, *Ind. Jour. Agri. Sc.*, **4**, 923, 1934; Ramdas and Katti, *ibid.*, **6**, 1163, 1936.

5 B. B. Ray, *Proc. Ind. Assoc. Cult. Sc.*, **8**, 23, 1923.

PROGRESS OF BOTANY DURING THE PAST TWENTY-FIVE YEARS.

By

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CONTENTS.

I. INTRODUCTION.

A good idea of the state of Botanical research in India towards the end of the 19th century can be had from Sir George King's [1] address entitled 'A Sketch of the History of Indian Botany' delivered to the Botany section of the Dover meeting (1899) of the British Association for the Advancement of Science. From this résumé it appears that the work done in India up to that time was confined mainly to systematic, geographical and economic studies; the systematic and geographical work was chiefly done by the Botanical departments of the provinces of Bengal, Madras, Bombay and Northern India. To co-ordinate the work of these departments,

[1] King, Sir George, *Rept. Brit. Ass. Adv. Sci.* (*Dover*), 904–919, 1889.

the Botanical Survey of India with headquarters at Calcutta was founded in 1889 'without removing either the officers or the four institutions to which they were attached from the financial or general control of the local administration within which they were respectively situated, the supreme Government making a small contribution of money for the purpose of exploring little-known districts and making itself responsible for the cost of publications called the "Records of the Botanical Survey of India"'.[1]

J. D. Hooker's[2] monumental *Flora of British India* in seven volumes was completed in 1897, and from this date preparations were being made for the publication of floras of the various provinces of India.

In the economic sphere Sir George Watt's[3] *Dictionary of the Economic Products of India*, completed in 1896, furnished a good foundation for further work.

In the first decade of the present century, floristic investigations of different parts of India were continued. Floras for Bengal by D. Prain[4] and Bombay Presidency including Sind by T. Cooke[5] were published between 1901–1908. The publication of a Flora of the Upper Gangetic plain including the area of the United Provinces and Oudh, the Malwa plateau, Eastern Rajputana and Delhi was commenced by J. F. Duthie,[6] and two volumes including families up to the Plantaginaceæ were published.

It was during this decade also that the Imperial and Provincial departments of Agriculture in their present form were established. The Imperial Agricultural Research Institute was established at Pusa about 1904. The Mycologists and Economic Botanists appointed on the staff of these departments commenced a series of researches in their respective spheres of work.

There was, however, not much provision for research in Botany in any of the Universities or colleges attached to them. It is true that occasionally botanists like Mr. C. B. Clarke and Dr. George Watt were appointed to the Indian Educational Service in Bengal, but they do not seem to have had much to do in training botanists; Mr. Clarke was employed in inspecting Schools and Dr. Watt was soon transferred to be Reporter on Economic Products of India. Prof. P. Brühl, who was then a Professor of the Sibpur Engineering College, did some work in his spare time, but even he was not a teacher of Botany.

During the period under review (1910–35) a great change has come over Botanical Research in India. This was in a large measure due to the establishment of teaching and research departments in

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1 *Vide* reference 1, p. 742.
2 Hooker, Sir J. D., *Flora of British India*, **1–7**, 1875–1897.
3 Watt, Sir G., *Dictionary of the Economic Products of India*, **1–6**, 1889–96.
4 Prain, D., *Bengal Plants*, **1**, **2**, 1903.
5 Cooke, T., *Flora of the Presidency of Bombay*, **1**, **2**, 1901–08.
6 Duthie, J. F., *Flora of the Upper Gangetic Plain*, **1**, **2**, 1903–11.

the Universities and Colleges in India, mainly during the post-war period.

The extent of this change becomes evident from the annual reports of the Botanical Survey of India, and of the Board of Scientific Advice for India up to the year 1923, in which are included summaries of botanical work done in India during the period. From these reports and from the Proceedings of the Indian Science Congress, one realizes the fact that whereas up to the year 1920 or thereabouts, research work in Botany was mainly carried on by Government departments like the Botanical Survey or by officers of the Agricultural departments and was mainly floristic and systematic in character, in the period since 1920, a continually increasing amount of work, in all branches of Botany has been done by the staffs of the Botany Departments of the Universities and the colleges affiliated to them. This is principally due to the introduction of Honours and Post-Graduate courses in most Universities. The University departments are now generally staffed by persons with research qualifications, most of whom are actively engaged in original investigations.

The foundation of the Indian Botanical Society in 1921 and the publication of its journal, of which 16 volumes have already been published, has been an additional stimulus to the progress of Botany in India.

In the present chapter it is proposed to give a short account of the main trends of Botanical research in India during the past twenty-five years under the headings: Morphology, Physiology, Systematic Botany, Palæobotany, Applied Botany, and Plant Geography and Ecology.

I take this opportunity to express my indebtedness to Professor P. Parija, Ravenshaw College, Cuttack, who has contributed the section on Plant Physiology, Professor B. Sahni, F.R.S. of the Lucknow University, for information in regard to Palæobotany, to the Economic Botanists and Mycologists of the Imperial, Provincial and States departments of Agriculture, and the Forest Botanist and Forest Mycologist at the Forest Research Institute, Dehra Dun, for information on Applied Botany, Brevet-Colonel R. N. Chopra, I.M.S., for information on the study of medicinal plants, and to friends and colleagues in the Universities for information on work done in their institutions. Without this help it would not have been possible for me to compile this account. I also express my sincere thanks to the Editor, Dr. B. Prashad, for the consideration he has shown to me in extending the time-limit for the receipt of the typescript.

II. Morphology.

A considerable amount of work on the morphology of the Indian flowering plants has been done during this period. The

earlier work is more or less of a descriptive character and includes a record of abnormalities and variations from the normal structure, the study of floral biology and methods of pollination, fruit dispersal and methods of perennation, etc. The later work includes studies on the internal anatomy (from the physiological as well as the systematic point of view), life-history and embryology. Of these the following may be mentioned :—

(*a*) *Anatomy.*

Sabnis [1] has studied the physiological anatomy of the plants of the Indian desert. Mullan [2] has investigated the physiological anatomy of Indian halophytes. The anatomy of climbing plants has been described by Dastur [3] and his co-workers. Gupta [4] has studied the effects of edaphic factors on the anatomy of certain species.

Maheswari [5] studied the morphology of *Boerrhavia diffusa* and the structure of the stem of *Rumex crispus*. Bhargava [6] investigated the morphology of *Boerrhavia repanda*, and Johri [7] the morphology of the Alismaceæ.

Joshi [8] and co-workers have directed their attention to the anatomy and life-history of various members of the Polygonaceæ, Chenopodiaceæ, Amarantaceæ, Thymelæaceæ and Araliaceæ.

The anatomy of the stem and root of *Eriocaulon septangulare* has been described by Solomon. [9] Gupta [10] has studied the wood anatomy and theoretical significance of Homoxylous angiosperms. Rao [11] has studied the morphology of *Antigonon leptopus* and members of the Capparidaceæ. Ghosh [12] described the stem anatomy of the Cucurbitaceæ with reference to its systematic value.

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1 Sabnis, T. S., *Journ. Ind. Bot.*, **1**, 33–43, 65–83, 97–114, 183–205, 227–251, 277–295, 1919-20 ; **2**, 1–20, 61–79, 93–115, 157–163, 217–235, 271–299 ; 1921.

2 Mullan, D. P., *Journ. Ind. Bot. Soc.*, **11**, 103–118, 1932 ; 285–302, 1933 ; **12**, 165–182, 235–253, 1933.

3 Dastur, R. H. and Kanga, P. M., *Ann. Bot.*, **41**, 671, 1927 ; Dastur R. H. and Kapadia, G. A., *Journ. Ind. Bot. Soc.*, **10**, 110–121, 1931.

4 Gupta, P. S., *Journ. Ind. Bot. Soc.*, **15**, 1–18, 1936.

5 Maheswari, P., *Journ. Ind. Bot. Soc.*, **8**, 89–117, 219–234, 1929.

6 Bhargava, H. R., *Journ. Ind. Bot. Soc.*, **11**, 303–326, 1932.

7 Johri, B. M., *Journ. Ind. Bot. Soc.*, **14**, 49–66, 1935 ; *Proc. Ind. Acad. Sci. B*, **1**, 340–348, 1935 ; *Proc. Ind. Acad. Sci. B*, **1**, 33–48, 1935.

8 Joshi, A. C., *Journ. Ind. Bot. Soc.*, **10**, 209–212, 1931 ; *ibid.*, **10**, 213–231, 1931 ; *ibid.*, **10**, 265–291, 1931 ; *ibid.*, **14**, 349-50, 1935 ; *ibid.*, **15**, 77–86, 1936 ; *ibid.*, **15**, 91–104, 1936 ; *ibid.*, **16**, 297–300, 1937 ; Joshi, A. C. and Venkata Rao, C., *ibid.*, **13**, 201–236, 1934 ; Joshi, A. C. and Sita Ram Rao, V., *ibid.*, **13**, 169–186, 1934.

9 Solomon, R., *Journ. Ind. Bot. Soc.*, **10**, 139–144, 1931.

10 Gupta, K. M., *Journ. Ind. Bot. Soc.*, **13**, 71–101, 1934.

11 Rao, V. S., *Journ. Ind. Bot. Soc.*, **15**, 105–114, 1936 ; *ibid.*, **15**, 71–76, 335–344, 1936.

12 Ghosh, E. N., *Journ. Ind. Bot. Soc.*, **11**, 259–270, 1932.

Heterarchic roots of *Enhydra fluitans* have been studied by Majumdar.[1] Sahni[2] has discussed the explosive mechanism of the fruit of *Viscum japonicum* Thunb., while Parija and Mallik[3] have described the bursting of the fruit of *Impatiens balsmina*.

(b) *Embryology*.

Investigations on the subject commenced only about 1920, and the number of papers published since this date has been increasing steadily. The chief centres of work are Agra, Allahabad, Benares, Calcutta, Bangalore, Madras and Ahmedabad, though work has also been reported from Ajmer, Nagpur and Coimbatore. Maheswari[4] published in 1935 a résumé of the work done in *Current Science*, which has been used in preparing the following summary :—

Dastur[5] investigated the structure and development of the ovules of *Hydnora africana*. Rao[6] and Ekambaram and Panje[7] studied the morphology of *Balanophora* sp. from Coorg-Malabar forests.

Tiwary[8] discovered polyembryony in *Eugenia jambolana*. Tiwary and Rao[9] studied the development of the embryo-sac in another member of the Myrtaceæ, *Callistemon linearis*, and found it to be quite normal.

Joshi[10] studied the megaspore and embryo-sac formation in *Argemone mexicana* ; these results were supplemented and modified by Bose and Banerji,[11] and Bose.[12]

Joshi[13] and his collaborators studied the embryology of *Tinospora cordifolia* and *Ammania baccifera*.

Agharkar and Banerji[14] investigated the development of the embryo-sac in *Carica papaya*. Banerji[15] described the life-history of *Corchorus olitorius* and *C. capsularis*; he also studied the female gametophyte of *Colocasia antiquorum*. Banerji and Bhaduri[16] recorded the presence of polyembryony in *Nicotiana*

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1 Majumdar, G. P., *Journ. Ind. Bot. Soc.*, **11**, 225–227, 1932.
2 Sahni, B., *Journ. Ind. Bot. Soc.*, **12**, 96–101, 1933.
3 Parija, P. and Mallik, P., *Journ. Ind. Bot. Soc.*, **15**, 59–62, 1936.
4 Maheswari, P., *Curr. Sci.*, **3**, 599–605, 1935.
5 Dastur, R. H., *Trans. Roy. Soc. South Africa*, **10**, 1922.
6 Rao, L. N., *Curr. Sci.*, **1**, 134, 135, 1932.
7 Ekambaram, T. and Panje, *Proc. Ind. Acad. Sc., B*, **1**. 452–470, 522–543 ; 1935.
8 Tiwary, N. K., *Journ. Ind. Bot. Soc.*, **5**, 1926.
9 Tiwary, N. K. and Rao, V. S., *Curr. Sci.*, **2**, 339, 340, 1934.
10 Joshi, A. C., *Journ. Ind. Bot. Soc.*, **12**, 83–90, 1933.
11 Bose, P. K. and Banerji, I., *Curr. Sci.*, **2**, 94, 1933.
12 Bose, P. K., *Journ. Ind. Bot. Soc.*, **16**, 197–208, 1937.
13 Joshi, A. C. and Raman Rao, V. V., *Curr. Sci.*, **3**, 62, 63, 1934.
14 Agharkar, S. P. and Banerji, I., *Journ. Dept. of Science, Calcutta University*, 1930.
15 Banerji, I., *Journ. Ind. Bot. Soc.*, **11**, 82–85, 1932 ; 228–239 : 1932.
16 Banerji, I. and Bhaduri, P. N., *Curr. Sci.*, **1**, 310, 311, 1933.

plumbaginifolia. Bhaduri [1] made a detailed study of the life-history of *Solanum melongena*. He further extended his work to several other members of the Solanaceæ and pointed out the formation of two types of endosperm cells, some with the triploid number and others with the diploid number of chromosomes. Roy,[2] Datta,[3] and Paul [4] have made interesting contributions to the embryology of the Leguminoseæ.

Seshagiriah [5] made interesting contributions to the life-history of *Zeuxine sulcata*. Narasimha Murthi [6] and Johri [7] studied the life-history of *Limnophyton obtusifolium*, and Narasimha Murthy [8] elucidated the life-histories of four members of the Commelinaceæ, *Cyanotis cristata*, *Cyanotis axillaris*, *Aneilema spiratum* and *Zebrina pendula*.

Maheswari [9] and his students have published a large number of papers. Johri [10] investigated the life-history of *Cuscuta reflexa*, *Berberis nepalensis* and *Acalypha indica*. Bhargava [11] studied the life-history of some members of the Centrospermeæ.

Puri,[12] Gupta,[13] Singh and Shivapuri [14] have made contributions to the life-history of the Moringaceæ, Potamogetonaceæ, Lemnaceæ, Leguminoseæ, Ulmaceæ, Liliaceæ, etc.

Mathur [15] studied the life-history of *Convolvulus arvensis*. Richaria [16] has been working on the development of the stamens of Asclepiadaceæ and has reported that while species of *Hemidesmus*, *Cryptostegia* and *Cryptolepsis* have four sporangia, *Calotropis*, *Dœmia*, *Holostemma* and *Pergularia* have only two.

Dutt and Rao [17] have studied the development of the embryo and embryo-sac of Sugarcane.

Agharkar and Bhaduri [18] have studied variations in chromosome numbers in Musaceæ.

1 Bhaduri, P. N., *Journ. Ind. Bot. Soc.*, **11**, 202–224, 1932.

2 Roy, B., *Ind. Journ. Agr. Res.*, **3**, 1098–1107, 1933.

3 Datta, R. M., *Journ. Ind. Bot. Soc.*, **13**, 277–299, 1934.

4 Paul, A. K., *Journ. Ind. Bot. Soc.*, **16**, 151–157, 1937.

5 Seshagiriah, K. N., *Curr. Sci.*, **1**, 102, 1932 ; *ibid.*, **3**, 205, 206, 264, 1934.

6 Narasimha Murthi, S. K., *Curr. Sci.*, **2**, 53-54, 1933.

7 Johri, B. M., *Journ. Ind. Bot. Soc.*, **14**, 49–66, 1935.

8 Narasimha Murthy, K. L., *Curr. Sci.*, **3**, 258-59, 1934.

9 Maheswari, P. and Singh, U. B., *Journ. Ind. Bot. Soc.*, **9**, 31–39, 1930 ; Maheswari, P., *Proc. Ind. Acad. Sc. B.*, **1**, 197–204, 1934-35 ; *Journ. Ind. Bot. Soc.*, **10**, 241–264, 1931.

10 Johri, B. M., *Proc. Ind. Acad. Sc. B.*, **1**, 283–290, 1934-35.

11 Bhargava, H. R., *Proc. Ind. Acad. Sc. B.*, **1**, 271–78, 1934-35.

12 Puri, V., *Proc. Ind. Acad. Sc. B.*, **1**, 279–82, 1934-35.

13 Gupta, B. L., *Journ. Ind. Bot. Soc.*, **13**, 51–66, 1934.

14 Singh, B. and Shivapuri, T. N., *Proc. Ind. Acad. Sc. B.*, **1**, 423–34, 1934-35.

15 Mathur, K. L., *Curr. Sci.*, **3**, 159-160, 1934.

16 Richaria, R. H., *Curr. Sci.*, **2**, 340-341, 1934.

17 Dutt, N. L. and Subba Rao, K. S., *Ind. Journ. Agr. Sc.*, **3**, 37–56, 1933.

18 Agharkar, S. P. and Bhaduri, P. N., *Curr. Sci.*, **3**, 615–17, 1935.

(c) *Teratology.*

The study and record of abnormalities of Phanerogams has been undertaken by many authors, including Agharkar,[1] Sabnis,[2] Singh,[3] Kashyap,[4] Sahni,[5] Hallberg,[6] Joshi[7] and others.

The study of plant galls has recently been started; Ramachandra Rao,[8] Raman[9] and Mani[10] have been the principal workers in this field.

III. PHYSIOLOGY.

In the history of Botany as a whole, plant physiology followed in the wake of morphology in the broadest sense. The same is true of botany in India, and the development of plant physiology is a comparatively recent event. At the beginning of the quarter-century under consideration we find but a few workers at one or two centres engaged in physiological work. Such centres were the Imperial Agricultural Research Institute at Pusa, the Indian Institute of Science, Bangalore, the provincial agricultural research stations, and the University of Calcutta.

With the general advancement of learning, greater interest, both philosophical and economic, was taken in the life of the plant and in consequence plant physiology became more and more prominent. Indian students went abroad and studied plant physiology in various Universities and came back to start centres of study in India.

During the quarter-century, the famous Bose Research Institute was founded by Sir Jagadis Chandra Bose in Calcutta. This is a unique instance in India of a professor, devoted to research, who spent his life's savings for the foundation of a research institute.

Another notable institutional development is the foundation of the Agricultural Research Institute of the Benares Hindu University, which is devoted to training post-graduate students, and research in agricultural plant physiology. The impetus given

1 Agharkar, S. P., *Journ. Ind. Bot. Soc.*, **4**, 18–20, 1925; *ibid.*, **5**, 17-18, 1926.

2 Sabnis, T., *Journ. Ind. Bot. Soc.*, **10**, 21–25, 1931.

3 Singh, T. C. N., *Journ. Ind. Bot. Soc.*, **5**, 16, 1926; *ibid.*, **9**, 250, 1930; *ibid.*, **10**, 134-135, 1931; *ibid.*, **12**, 65–68, 1933; *ibid.*, **13**, 41–45, 1934; *ibid.*, **14**, 313–324, 1935; *Proc. Ind. Sc. Congr.*, **18**, 270-271, 1931; *ibid.*, **19**, 331, 1932.

4 Kashyap, S. R., *Journ. Ind. Bot. Soc.*, **4**, 217–219, 1935; *ibid.*, **4**, 312–314, 1925.

5 Sahni, B., *Journ. Ind. Bot. Soc.*, **12**, 50–55, 1933.

6 Hallberg, F., *Journ. Ind. Bot. Soc.*, **3**, 1–9, 1922.

7 Joshi, A. C., *Journ. Ind. Bot. Soc.*, **12**, 255–271, 1933.

8 Ramachandra Rao, Y., *Journ. A.S.B., N.S.*, **13**, 299–306, 1917.

9 Raman, A. H. Sundar, *Journ. Ind. Bot. Soc.*, **4**, 1–17, 35–49, 1925.

10 Mani, M. S., *Journ. A.S.B., Science*, **1**, 93–108, 1935; *Curr. Sci.*, **3**, 109, 1934.

to the study of plant physiology by Prof. R. S. Inamdar in the Botany Department of the University resulted in the development of this Institute.

The Institute of Plant Industry at Indore also deserves mention, as some valuable plant physiological work has been carried out in this Institute.

The Vivekananda Laboratory, Almora, is devoted to plant physiology under the direction of Mr. Bosi Sen.

The most important agency which has fostered research in plant physiology within recent years, however, is the Imperial Council of Agricultural Research, which has made various grants for research in plant physiology.

In addition to these new institutions, the institutions and departments of botany which existed before the period under review, developed study and research in plant physiology. A large amount of work has been produced, some of which is of fundamental importance.

Lack of space precludes a complete list of publications being given here, and it is proposed to indicate here only the directions in which physiological investigations have progressed.

Bose [1] and his collaborators investigated the life processes of plants from the vitalistic standpoint and these studies have been published in the form of books and other periodic contributions. So far as the absorption and ascent of sap are concerned, the vitalistic standpoint has been assailed by Ekambaram and his co-workers [2] by their study of absorption of poisons by cutshoots of plants. These authors do not find support for the vitalistic view of absorption and ascent of sap.

Sen [3] has directed his attention to the study of the nature of protoplasm.

Dastur [4] and his students and Singh [5] and his students have devoted a good deal of attention to the question of absorption of ions by plants from cultures. As this important question has great economic bearing, many workers at various centres have turned their attention to this problem.

Ghosh [6] has studied the kinetics of photosynthesis in plants from the theoretical standpoint.

Plant metabolism is another subject which rightly claimed the attention of a large number of workers. Our knowledge of the

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1 Bose, Sir J. C., *Researches on the irritability of Plants*, 1913 ; *The Physiology of the Ascent of Sap*, 1923 ; *The Physiology of Photosynthesis*, 1924.

2 Ekambaram, T. and Rao, I. M., *Journ. Ind. Bot. Soc.*, **12**, 293, 1933.

3 Sen, B., *Proc. Roy. Soc., B*, **94**, 216, 1933 ; *Proc. Roy. Soc., B*, **103**, 272, 1928 ; *Ann. Bot.*, **48**, 143, 1934.

4 Dastur, R. H., *Ann. Bot.*, **38**, 779, 1924 ; Dastur, R. H. and Baptista, E., *Ind. Journ. Agri. Sci.*, **1**, 166, 1931 ; Dastur, R. H. and Cooper, R. E., *Ind. Journ. Agri. Sci.*, **2**, 99–138, 1932.

5 Singh, B. N. and Lal, K. N., *Ann. Bot.*, **49**, 291, 1935.

6 Ghosh, J. C., *Jahrbüch. wiss. Bot.*, **69**, 572–586, 1928.

working of tropical plants is not so deep as that of the temperate regions. Most of the workers on this problem have attempted, with considerable success, to throw light on the metabolism of tropical plants; Inamdar may be regarded as the pioneer in this field. On the synthetic side of metabolism, the various publications of Dastur [1] also deserve mention.

The problem of nitrification of the soil has been attacked by Dhar and collaborators and Subrahmanyan and his co-workers. Dhar [2] has advanced a theory of photo-fixation of nitrogen which, if confirmed, will be an interesting discovery, while Subrahmanyan [3] has elucidated a number of points in connection with the functioning of *Nitrosomonas*. The problem of nitrification of rice-fields is being studied in the laboratory of Ghosh at Dacca.

The influence of mineral nutrients on the quality of fodder and grains has received fair attention during the period under review.

On the katabolic side of metabolism, the works of Inamdar and co-workers [4], Parija and co-workers [5] and Ranjan and co-workers [6] deserve mention. Various aspects of plant respiration have been studied by these authors.

In the desire to study the physiology of economic plants, attention has shifted from the pure physiological study of irritability to the study of movements. The impetus given to this branch of physiology by the late Sir J. C. Bose still operates at the Bose Institute. Saxton [7] has made interesting observations on nyctinasty, and put forward the theory that the night position is normal to plants and that nyctinasty does not exist. Dastur [8] and his students have carried out some work on the structure and function of tendrils in Cucurbitaceæ, while some work on curvatures has been done at Ravenshaw College, Cuttack. Sengupta [9] has studied the rheotropism of roots.

Work on enzymic activities also has been done in connection with the problems noted above.

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[1] Dastur, R. H. and Asana, R. D., *Ann. Bot.*, **46**, 879, 1932; Dastur, R. H. and Soloman, S., *Ann. Bot.*, *N.S.*, **1**, 147, 1937.

[2] Dhar, N. R. and Seshacharyulu, E. V., *Proc. Nat. Acad. Sci. Ind.*, **6**, 99, 1936; Dhar, N. R. and Mukherjee, S. K., *ibid.*, 289, 1936.

[3] Subrahmanyan, V. and Bhaskaran, T. R., *Proc. Nat. Inst. Sc. India*, **3**, 163–174, 1937.

[4] Inamdar, R. S., Singh B. M. and Pande, *Ann. Bot.*, **39**, 281, 1925; Inamdar, R. S. and Singh, B. N., *Journ. Ind. Bot. Soc.*, **6**, 133, 1927.

[5] Blackman, F. F. and Parija, P., *Proc. Roy. Soc. B*, **103**, 412–45, 1928; Parija, P., *ibid.*, 446–490, 1928; *Ind. Journ. Agri. Sci.*, **4**, 399, 1934; Parija, P. and Saran, A. B., *Anns. Bot.*, **48**, 1934; *Journ. Ind. Bot. Soc.*, **11**, 271, 1932.

[6] Ranjan, S., Thesis for Doctorate, Toulouse, 1932; Ranjan, S. and Mallick, A. K., *New Phyt.*, **30**, 355, 1931; Ranjan, S. and Khan, Z. A., *Journ. Ind. Bot. Soc.*, **13**, 17, 1934.

[7] Saxton, W. T., *Journ. Ind. Bot.*, **3**, 127–142, 1922.

[8] Dastur, R. H. and Billimoria, M. C., *Journ. Ind. Bot. Soc.*, **11**, 148, 1932; Dastur, R. H. and Kanga, P. M., *Ann. Bot.*, **41**, 671, 1927.

[9] Sengupta, J., *Ztschr. Bot.*, **21**, 353–98, 1929.

IV. Systematic Botany.

(a) *Algæ.*

The position of the study of Algæ up to 1921 was summarized by Dudgeon [1] as follows: ' In addition to a few older scattered references, Ghose [2] published an account of the *Cyanophyceæ* of Lahore and Iyengar [3] worked out some *Volvocaceæ* of Madras, but very little is known about the other groups of Algæ occurring in India.'

Since that time a large amount of work on Indian Algæ has been carried out by the staffs of various Universities and by students working under their guidance. A review of the work done up to the year 1928 was given by Iyengar [4] in his Presidential Address to the Botany section of the 15th Indian Science Congress at Calcutta. The work on Freshwater Algæ during the years 1928-1932 was summarized by Ghose [5] in his Presidential Address to the Botany section of the 20th Indian Science Congress at Patna. It is, therefore, only necessary here to refer to the trends of algological work in India as revealed by recent literature.

Work on Algæ is being done mainly at Madras under Professor M. O. P. Iyengar, at Lahore under Dr. S. L. Ghose, at Calcutta by Dr. K. Biswas and by Mr. J. C. Banerji of the Calcutta University, by Mr. Handa at Rangoon, and by Professor Y. Bharadwaja at Benares. Other workers are Professor B. C. Kundu of Rajshahi and Dr. B. P. Pal of New Delhi, Mr. S. C. Dixit of Bombay, the late Mr. James Groves, and Mr. G. O. Allen, all of whom have confined their attention to the Charophyta.

The work at Madras is of a varied character, various groups of Algæ, including the marine types, being investigated. Of the Calcutta workers, Banerji is mainly engaged in a study of Myxophyceæ of Bengal. Biswas has studied the Myxophyceæ, Desmids, Diatoms and other groups of freshwater Algæ. Kundu and Pal have studied the Charophyta of Bengal and Burma respectively. Ghose and his collaborators have been working on Myxophyceæ, Chrysophyceæ, Chlorophyceæ, and other groups from the Punjab. Bharadwaja is a student of the Myxophyceæ.

Abdul Majeed [6] has studied the Diatoms of the Punjab plains. Nirula [7] has been working on the Algæ from Nagpur. Borgessen, [8]

1 Dudgeon, W., *Journ., Proc. A.S.B., N.S.*, **18**, 100, 1922.
2 Ghose, S. L., *Journ. Ind. Bot.*, **1**, 8–13, 1919.
3 Iyengar, M. O. P., *Journ. Ind. Bot.*, **1**, 330–336, 1920.
4 Iyengar, M. O. P., *Proc. Ind. Sc. Congr.*, **15**, 207–222, 1928.
5 Ghose, S. L., *Proc. Ind. Sc. Congr.*, **20**, 279–299, 1933.
6 Abdul Majeed, M., *Journ. Proc. A.S.B., N.S.*, **29**, 307, 309, 1933 ; *Curr. Sci.*, **3**, 626, 1935.
7 Nirula, R. L., *Proc. Ind. Sc. Congr.*, **18**, 258-259, 1931.
8 Borgessen, F., *Journ. Ind. Bot. Soc.*, **9**, 151–174, 1930 ; **11**, 51–70, 1931 ; **12**, 1–16, 1933 ; **16**, 1–56, 311–358, 1937.

who visited the western coast of India recently, has described many Algæ from the Malabar coast and South India ; his account forms the most important contribution to our knowledge of the Marine Algæ of the Malabar coast and South India up to now.

Much of the work is systematic and descriptive, but there are indications of ecological and life-history studies being undertaken.

(b) *Fungi.*

Mycological work is being done in India by the Imperial and Provincial departments of Agriculture and the Universities. As Dr. Burns has summarized the work done by the Agricultural departments in the Chapter on the Progress of Agricultural Science, it is necessary to refer here only to the work done in the Indian Universities.[1]

Among Indian Universities which have more particularly turned their attention to the study of Fungi are the Universities of the Punjab, Agra, Allahabad, Calcutta and Lucknow.

At the Botanical laboratory in Lahore, H. Chaudhuri and his students have worked on a variety of Fungi including Soil and Aquatic Fungi, slime moulds and mycorrhiza, bacteria and certain bacterial diseases, including the bacterial diseases of wheat. Chaudhuri has also published a report on the Citrus diseases of the Punjab.

Fungus work in Allahabad has included : (*a*) collection and identification of Indian Fungi, (*b*) determination of the nutritive value of natural media prepared from Indian fruits and vegetables, and (*c*) detailed cultural studies. K. L. Saksena, J. Mitter and Tandon, and H. Sydow and J. H. Mitter have also published various descriptive lists of Indian Fungi in which several new genera and species have been described. R. K. Saksena has also published the results of his studies on the cytology and biology of certain species of *Pythium*.

At Agra K. C. Mehta has been doing very important work on the annual recurrence of cereal rusts in the plains of India, which, according to him, is due to windblown uredospores disseminated from the hills where they oversummer. He has found that as far as the plains are concerned, *Berberis* and *Thalictrum* seem to play little part in the annual outbreaks of black and brown rusts. The number of physiologic races of each of the three rusts of wheat met with in India so far is very small as compared to most of the other wheat-producing countries. Further the area under wheat in the hills, where rusts oversummer is very small, being not more than 5%.

Mehta, therefore, considers that the possibility of controlling rusts is infinitely greater in India than elsewhere.

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[1] Mitter, J. H., *Proc. Ind. Sc. Congr.*, **21**, 221–245, 1935.

Destruction of self-sown wheat plants and tillers, and suspension of wheat cultivation for 2-3 years is one method, and the cultivation of rust-resistant varieties only in the hills is the other. Since 1930 these investigations have been financed by the Imperial Council of Agricultural Research and a laboratory is maintained at Simla for the purpose.

In the Calcutta University, S. R. Bose has been studying the Polyporaceæ of Bengal for many years. He has also studied the biology of wood rotting fungi, the sexuality of the Basidiomycetes and the effects of radiation on some Polypores in culture. Banerji [1] has published descriptions of the Thelephoraceæ and Hydnaceæ of Bengal.

Dasgupta [2] has published interesting work on the phenomenon of Saltation in Fungi, based on his studies of species of *Cytosporina*, *Phomopsis* and *Diaporthe*.

Ajrekar [3] has done a considerable amount of work on various diseases of crop plants (referred to in the chapter on Agriculture) and also on the Mucorineæ of Bombay, and other pathogenic fungi. Narasinham [4] has studied the Phalloideæ of Mysore. Other work on a variety of topics in reference to Fungi is also being done at several centres.

The publication of their work on 'The Fungi of India' by Butler and Bisby [5] in 1931 is an event of great importance for the systematic study of Fungi. After a short historical account, a list of 2,350 species of Fungi recorded from India is given, together with the localities from which they were collected and their host plants. Full references to literature, a list of synonyms and other names applied to them, a complete bibliography and a host index, which have been added, make this publication invaluable to students of this group.

(c) *Lichens.*

The only publication dealing with the Lichens of India published during the period is Chopra's [6] 'Lichens of the Himalayas', Part I. Chopra has also studied the Lichens of Simla and Vaishno Devi (Kashmir).

1 Banerji, S. N., *Journ. Ind. Bot. Soc.*, **14**, 13–48, 1935; *Curr. Sci.*, **2**, 478-479, 1934; *Ann. Myc.*, **34**, 76–78, 1936.

2 Dasgupta, S., *Lucknow Univ. Studies*, **5**, 1936; *Phil. Trans. Roy. Soc. B*, **223**, 121–161, 1934.

3 Ajrekar, S. L., *Journ. Ind. Bot. Soc.*, **10**, 195–204, 1931; *ibid.*, **11**, 127–131, 1932.

4 Narasinham, J., *Journ. Ind. Bot. Soc.*, **11**, 248–254, 1932.

5 Butler, E. J. and Bisby, G. R., *Sc. Mon. Imp. Council. Agr. Res.*, **1**, 1931.

6 Chopra, G. L., *Publ. Bot. Dept. Punjab Univ.*, **4**, 1934.

(d) *Bryophyta.*

Liverworts

The most important work on the Liverworts of India during the period is by the late Professor S. R. Kashyap and his students. A large number of papers were published by him on 'New and little known Liverworts of the Western Himalayas and the Punjab',[1] which led finally to the publication of the 'Liverworts of the Western Himalayas and the Punjab plains', Parts I[2] and II.[3] Associated with him were several of his students, Messrs. R. S. Chopra, B. L. Sethi and others. In his Presidential Address to the Botany section of the 6th Indian Science Congress at Bombay [4], he discussed the relationships of the Liverworts in the light of some recently discovered forms. He [5] later also discussed the liverwort flora of Sikkim.

Pande [6] has studied the liverworts of Nainital and the adjoining hills, and some epiphyllous liverworts from South India and has reviewed the literature on the subject, in 1936.

Khanna [7] has studied the Marchantiales and Anthocerotales of Burma and described some new species. He has also published descriptions of two new species of *Anthoceros* from Travancore.

Tiwary [8] has studied the germination of the spores of *Cyathodium.*

Mosses

Sedgwick [9] studied the mosses of the Bombay Presidency and published the results in the Journal of the Bombay Natural History Society. In several papers Dixon [10] described the mosses collected during the Abor Expedition and those from Southern India, Ceylon and other parts of India.

Brühl's [11] 'Census of Indian Mosses' based on Brotherus' work in the 'Natürlichen Pflanzenfamilien' 2nd ed. (prepared in 1924 but published in 1931) summarizes our knowledge of the Indian mosses and their distribution up to that year. As a result of this census he arrived at the interesting conclusion that there is a marked division line between the Western and the Eastern Himalayas. 'This

1 Kashyap, S. R., *New Phyt.*, **13**, 206, 1914; *ibid.*, **13**, 306, 1914; *ibid.*, **14**, 1, 1915; *Journ. Bomb. Nat. Hist. Soc.*, **24**, 343, 1916; *Journ. Bomb. Nat. Hist. Soc.*, **25**, 279, 1917.

2 Kashyap, S. R., *Publ. Bot. Dept. Punjab Univ.*, **1**, 1929.

3 Kashyap, S. R. and Chopra, R. S., *Publ. Bot. Dept. Punjab Univ.*, **2**, 1933.

4 Kashyap, S. R., *Proc. Ind. Sc. Congr.*, **6**, clii–clxvi, 1919.

5 Kashyap, S. R., *Proc. Ind. Sc. Congr.*, **17**, 287, 288, 1930.

6 Pande, S. K., *Proc. Ind. Sc. Congr.*, **18**, 264, 1931; *Journ. Ind. Bot. Soc.*, **15**, 221–233, 1936.

7 Khanna, L. P., *Journ. Burma Res. Soc.*, **16**, 227–229, 1927; *ibid.*, **17**, 270–282, 1927; *Journ. Ind. Bot. Soc.*, **8**, 118–125, 1929; *ibid.*, **15**, 235–240, 1936; *Journ. Bomb. Nat. Hist. Soc.*, **39**, 357–360.

8 Tiwary, N. K., *Journ. Ind. Bot. Soc.*, **14**, 167–171, 1935.

9 Sedgwick, L. J., *Journ. Bomb. Nat. Hist. Soc.*, **17**, 370, 1913-14.

10 Dixon, H. N., *Rec. Bot. Surv. Ind.*, **6**, 57–73, 75–89, 1914.

11 Brühl, P., *Rec. Bot. Surv. Ind.*, **13**, 1–135; *ibid.*, 1–152, 1931.

division line appears to be situated where the single main chain of mountains in the Eastern and Central parts breaks up into several chains in the west, the moss flora in the latter region being closely related with those of Northern Persia, the Caucasus and the Alps, whilst the Eastern region shows affinities on the one hand with Southern India and Ceylon, on the other hand with Burma and Malaya.' Brühl and Sarkar [1] also published descriptions of some new species of mosses from Bengal.

Badhwar [2] has studied the distribution of the mosses of the western Himalayas and the Punjab plains. Gupta [3] described a new species of *Physcomitrellopsis* from Benares. Sinha [4] has studied the mosses of Naini Tal. Singh [5] and Majumdar [6] have investigated vegetative reproduction in some Indian mosses.

(e) *Pteridophyta.*

Kashyap [7] made an important contribution to our knowledge of the group by his investigation of the gametophyte of *Equisetum debile*. Sethi [8] made further contributions to the same subject, while Phatak [9] has studied various aspects of the gametophyte of *Equisetum debile* var. *Pashan*.

N. Chowdhury [10] published an important paper on 'Notes on some Indian species of Lycopodium with remarks on the distribution of that genus in India' in which he discussed their distribution, anatomy, modes of vegetative reproduction and epidermal structure. Mahabale [11] has reported the discovery of the prothallus of *Lycopodium Cernuum* from Karanzol on the Portuguese West India Railway.

Miss Bancroft [12] studied the formation of perennating tubers in two species of *Selaginella* from the Himalayas. Majumdar [13] described the anatomical structure of some Selaginellas from the point of view of the Stelar theory. Ghose [14] has recorded the proliferation of the cone in a species of *Selaginella* from Garhwal.

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1 Brühl, P. and Sarkar, N., *Journ. Dept. Sc. Cal. Univ.*, **10**, 1–12, 1929.

2 Badhwar, R. L., *Proc. Ind. Sc. Congr.*, **17**, 286, 1930.

3 Gupta, K. M., *Journ. Ind. Bot. Soc.*, **12**, 122–128, 1933.

4 Sinha, B. N., *Proc. Ind. Sc. Congr.*, **18**, 265, 1931.

5 Singh, T. C. N., *Proc. Ind. Sc. Congr.*, **18**, 265, 1931.

6 Majumdar, G. P., *Proc. Ind. Sc. Congr.*, **20**, 307, 1933.

7 Kashyap, S. R., *Ann. Bot.*, **28**. 163–181, 1914.

8 Sethi, M. L., *Ann. Bot.*, **42**, 729–38, 1928.

9 Phatak, V. G., *Proc. Ind. Sc. Congr.*, **19**, 308, 309, 1932; *Proc. Ind. Sc. Congr.*, **20**, 308, 1933.

10 Chowdhury, N., *Trans. Nat. Inst. Sc. Ind.*, **1**, 187–226, 1937.

11 Mahabale, T. S., *Journ. Ind. Bot. Soc.*, **16**, 145–149, 1937.

12 Bancroft, N., *Ann. Bot.*, **28**, 685–693, 1914.

13 Majumdar, G. P., *Proc. Ind. Sc. Congr.*, **18**, 268, 1931.

14 Ghose, S. L., *Journ. Bom. Nat. Hist. Soc.*, **24**, 616, 1916; *Proc. Lahore Phil. Soc.*, **2**, 1–9, 1920; *Proc. Ind. Sc. Congr.*, **19**, 308, 1932.

Ekambaram and Venkatanathan [1] have studied the sporogenesis in *Isoetes coromandelina*. Misra [2] has described the morphology and anatomy of a form of *Isoetes* from Benares.

Sahni [3] has discussed the theoretical significance of some abnormalities in the sporangiophores of the Psilotaceæ.

D'Almeida [4] has studied the Indian Ophioglossums. Vashisht [5] investigated the comparative anatomy of several species of *Ophioglossum*. Maheswari and Singh [6] have studied the morphology of *Ophioglossum fibrosum* Schum. Dixit, Mahabale and Deshpande [7] have studied the germination of the spores, morphology and variability in the species of *Ophioglossum* occurring near Poona. Mahabale [8] has described the gametophytes of several species of *Ophioglossum* from Poona.

The cytology of *Osmunda* and *Doodia* was described in several papers by Sarbadhikari.[9] The occurrence of superficial Sori in *Osmunda claytoniana* has been noted by Chowdhuri.[10]

Hans Raj [11] studied the anatomy and development of the sporangium of *Lygodium japonicum*. Cheema [12] studied the leaf-trace in the Polypodiaceæ. Mitra [13] investigated the morphology of some species of *Pteris* and *Adiantum*. The anatomy of several Mussoorie ferns has been described by Singh.[14] Singh [15] also studied the ferns from the Naini Tal district and described the ventilating system of certain Indian ferns.

Biswas [16] has studied the ferns and fern-allies of Burma. Blatter and D'Almeida [17] have published an account of the Bombay ferns.

Pande [18] studied the biology of *Marsilia erosa* from Lahore.

1 Ekambaram, T. and Venkatanathan, T. N., *Journ. Ind. Bot. Soc.*, **12**, 191–225, 1933.

2 Misra, R. D., *Proc. Ind. Sc. Congr.*, **22**, 254, 1935.

3 Sahni, B., *Journ. Ind. Bot.*, **3**, 185–191, 1923.

4 D'Almeida, J. F., *Journ. Ind. Bot.*, **3**, 58–65, 1922.

5 Vashisht, B. R., *Journ. Ind. Bot. Soc.*, **6**, 8–30, 1927.

6 Maheswari, P. and Singh, B., *Journ. Ind. Bot. Soc.*, **13**, 103–124, 1934.

7 Dixit, D. L. and Mahabale, T. S., *Proc. Ind. Sc. Congr.*, **21**, 299, 1934; *ibid.*, **21**, 300, 1934; Mahabale, T. S. and Deshpande, G. S., *Proc. Ind. Sc. Congr.*, **21**, 300, 1934.

8 Mahabale, T. S., *Proc. Ind. Sc. Congr.*, **24**, 264-65, 1937.

9 Sarbadhikari, P. C., *Ann. Bot.*, **38**, 1–26, 1924.

10 Chowdhuri, N. P., *Proc. Ind. Sc. Congr.*, **19**, 307, 1932.

11 Hans Raj, *Proc. Lahore Phil. Soc.*, **4**, 29–48, 1923.

12 Cheema, G. S., *Proc. Ind. Sc. Congr.*, **6**, clxix, 1919.

13 Mitra, M., *Proc. Ind. Sc. Congr.*, **6**, clxviii, 1919.

14 Singh, T. C. N., *Proc. Ind. Sc. Congr.*, **15**, 233, 1928.

15 Singh, T. C. N., *Proc. Ind. Sc. Congr.*, **18**, 268, 1931; *ibid.*, **19**, 309, 1932.

16 Biswas, K. P., *Proc. Ind. Sc. Congr.*, **22**, 255, 1935.

17 Blatter, E. and D'Almeida, J. F., *The Ferns of Bombay*, 1922.

18 Pande, S. S., *Proc. Lahore Phil. Soc.*, **4**, 1–28, 1923.

Kolhatkar [1] described the sporogenesis, male gametophyte and spermatogenesis of a *Marsilia* from Poona.

Mehra [2] studied the prothalli of several leptosporangiate ferns. Pandit and Mulay [3] investigated an *Azolla* from Khandala. Majumdar [4] has published a list of the ferns of Calcutta.

(*f*) *Gymnosperms.*

During the period under review a fair amount of work relating to the study of the life-history of various species of Gymnosperms has been done in India. Sahni [5] published an important paper 'On the structure and affinities of *Acmophyle Pancheri* Pilger', and later [6] described certain features in the seed of *Taxus baccata* and their bearing on the antiquity of the Taxineæ.

Saxton [7] published a note on the life-history of *Cedrus Deodara*. This material was later on studied by Inder Nath [8] who published a short account of the 'Life-history of *Cedrus Deodara*'. A further contribution on the same subject was published by Johri,[9] who described the development of its pollen grains.

Ghose [10] studied the morphology of *Agathis ovata*, and discussed the origin and relationships of the Araucarineæ.

Sahni and Mitra [11] described the vegetative structure and female organs of four species of *Dacrydium* from New Zealand.

Sethi [12] studied the life-history of *Pinus longifolia*.

Kashyap [13] described a number of abnormalities of the sporophylls of the male cone of *Cycas circinalis*.

Handa [14] described the life-history of *Thuja occidentalis*. Sahni and Singh [15] described the vegetative anatomy and female cones of *Fitzroya patagonica* Hook.

Several workers have studied the anatomy and life-history of *Ephedra foliata* (=*peduncularis*). Jagan Nath [16] and Chopra [17]

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1 Kolhatkar, G. G., *Proc. Ind. Sc. Congr.*, **21**, 301, 1934; *ibid.*, **24**, 264, 1937.

2 Mehra, P. N., *Proc. Ind. Sc. Congr.*, **19**, 307, 1932.

3 Pandit, B. R. & B. N. Mulay, *Proc. Ind. Sc. Congr.*, **18**, 267, 1931.

4 Majumdar, G. P., *Proc. Ind. Sc. Congr.*, **20**, 308-9, 1933.

5 Sahni, B., *Phil. Trans. R. Soc.*, *B*, **210**, 253–310, 1920.

6 Sahni, B., *Ann. Bot.*, **34**, 117–133, 1920.

7 Saxton, W. T., *Journ. Ind. Bot.*, **3**, 90, 1921.

8 Inder Nath, *Proc. Ind. Sc. Congr.*, **13**, 218-19, 1926.

9 Johri, B. M., *Proc. Ind. Acad. Sc. B.* **3**, 243–57, 1936.

10 Ghose, S. L., *Journ. Ind. Bot. Soc.*, **4**, 79–86, 89–100, 1924.

11 Sahni, B. and Mitra, *Ann. Bot.*, **41**, 75–89, 1927.

12 Sethi, M. L., *Proc. Ind. Sc. Congr.*, **8**, clxxix, 1921; *ibid.*, **9**, 116, 1922; *ibid.*, **14**, 215, 1927; *Journ. Ind. Bot. Soc.*, **7**, 105–51, 1928.

13 Kashyap, S. R., *Journ. Ind. Bot. Soc.*, **4**, 312–314, 1925.

14 Handa, M. R., *Journ. Burm. Res. Soc.*, **16**, 214–29, 1927.

15 Sahni, B. and Singh, T. C. N., *Proc. Ind. Sc. Congr.*, **12**, 195, 1925; *Journ. Ind. Bot. Soc.*, **10**, 1–20, 1931.

16 Jagan Nath, *Proc. Ind. Sc. Congr.*, **10**, 189-90, 1923.

17 Chopra, R. L., *Proc. Ind. Sc. Congr.*, **16**, 226-27, 1929.

studied the seedling anatomy, while the latter [1] also described the morphology and anatomy of *E. foliata* and *E. distachya*. Mehra [2] studied the male gametophyte and chromosome morphology of *E. foliata* and *E. gerardiana*. Maheswari [3] later described in greater detail the male and female gametophytes of *E. foliata*.

Sampathkumaram [4] has studied the life-history of *Gnetum scandens*. Besides these life-history studies several authors have recorded abnormalities and galls on various members of the Gymnosperms in India.

Biswas [5] has published a list of the living Conifers of the Indian Empire and discussed the distribution of the wild conifers of India.

(*g*) *Angiosperms*.

During the period under review considerable progress has been made in the publication of the floras of the various provinces of India. The flora of the Upper Gangetic plain, commenced by Duthie [6] and continued after his death by R. N. Parker is nearing completion: only the Gramineæ part yet remains to be published. The flora of the Madras Presidency commenced by Gamble [7] and continued by Fischer after his death, was completed in 1935. Haines [8] published an account of the 'Botany of Bihar and Orissa', accompanied by a general part in which he discussed the general character of the flora and its ecology. The publication of a flora of Assam by Kanjilal,[9] Das and others has also been commenced.

Several floras or lists of species occurring in smaller areas have also been published. Of these the following may be mentioned; Smith's account [10] of the vegetation of the Zemu and Llonakh valleys of Sikkim and of the alpine and subalpine vegetation of south-east Sikkim; Fyson's [11] Flora of the Nilgiri and Pulney hill tops which was enlarged later into the Flora of the South Indian Hill stations; Blatter's Flora of Aden,[12] Flora of Arabia,[13] Flora of

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[1] Chopra, R. L., *Proc. Ind. Sc. Congr.*, **16**, 225, 1929.

[2] Mehra, P. N., *Proc. Ind. Sc. Congr.*, **21**, 301, 1934; *ibid.*, **22**, 256-57, 1935.

[3] Maheswari, P., *Proc. Ind. Acad. Sc.. B*, **1**, 586–606, 1935.

[4] Sampathkumaram, M. A., *Proc. Ind. Sc. Congr.*, **12**, 195, 1925; *ibid.*, **13**, 225, 1926; *ibid.*, **17**, 290, 1930.

[5] Biswas, K., *Journ. Ind. Bot. Soc.*, **12**, 24–47, 1933; *Journ. Proc. A.S.B., N.S.*, **28**, 359–77, 1933.

[6] Duthie, J. F. and Parker, R. N., *Flora of the Upper Gangetic Plain*, **3**, 1915–29.

[7] Gamble, J. S. and Fischer, C. F. C., *Flora of the Presidency of Madras*, **1–3**, 1915–35.

[8] Haines. H. H., *The Botany of Bihar and Orissa*, **1–6**, 1921–25.

[9] Kanjilal, U. N., Kanjilal, P. C. and Das, A., *Flora of Assam*, **1**, 1–184, 1934.

[10] Smith, W. W., *Rec. Bot. Surv. Ind.*, **4**, 1911; *ibid.*, **4**, 1913.

[11] Fyson, P. F., *Flora of the Nilgiri and Pulney Hill tops*, **1–3**, 1915–20; *Flora of the South Indian Hill Stations*, **1-2**, 1932.

[12] Blatter, E., *Flora of Aden, Rec. Bot. Surv. Ind.*, **7**, 1916.

[13] Blatter, E., *Flora Arabica, Rec. Bot. Surv. Ind.*, **8**, 1419–35.

N. Coimbatore[1] and Flora of Cutch[2]; Blatter and Hallberg's Flora of the Indian desert[3] and Flora of the Persian Beluchistan and Mekran[4]; Blatter, Hallberg and McCann's[5] contributions towards a flora of Baluchistan: Annandale and Carter's[6] notes on the vegetation of Seistan: Sabnis'[7] Flora of Sind: Burkill's notes from a journey to Nepal[8] and Botany of the Abor Expedition[9]; Mayuranathan's[10] Flowering Plants of Madras City: Kashyap and Joshi's[11] Lahore District Flora: and Saxton and Sedgwick's[12] Plants of Northern Gujarat.

A revision of the Flora of the Bombay Presidency was undertaken by E. Blatter,[13] and several parts have been published. Calder, Ramaswami and Narayanaswami[14] have published a list of species and genera of Indian Phanerogams not included in Hooker's Flora of British India.

Forest floras, dealing mainly with the trees and shrubs and woody climbers, have been published for Chota Nagpur, and the Southern circle of the Central Provinces by Haines,[15] for Kumaon by Osmaston,[16] for Gorakhpur, Philibit, Oudh and Bundelkhand by Kanjilal,[17] for the Punjab, Hazara and Delhi by Parker,[18] for the Andamans by Parkinson,[19] and for the Berars by Witt.[20]

[1] Blatter, E., *Flora of North Coimbatore*, *Journ. Bomb. Nat. Hist. Soc.*, **17**, 1907.

[2] Blatter, E., *Flora of Cutch*, *Journ. Bomb. Nat. Hist. Soc.*, **19**, 1908.

[3] Blatter, E. and Hallberg, *Flora of the Indian Desert*, *Journ. Bomb. Nat. Hist. Soc.*, **26**, 1919.

[4] Blatter, E. and Hallberg, *Flora of Persian Beluchistan and Makran*, *Journ. Bomb. Nat. Hist. Soc.*, **25**, 1918.

[5] Blatter, E., Hallberg, F and McCann, C., *Journ. Ind. Bot. Soc.*, **1**, 1919.

[6] Annandale and Carter, H. G., *Journ. Proc. A.S.B.N.Sc.*, **15**, 267–297, 1919.

[7] Sabnis, T. S., *Journ. Ind. Bot. Soc.*, **3**, 1923 ; *ibid.*, **4**, 1924.

[8] Burkill, I., *Rec. Bot. Surv. Ind.*, **4**, 1910.

[9] Burkill, I., *Rec. Bot. Surv. Ind.*, **10**, 1924.

[10] Mayuranathan, P. V., *Bull. Madras Govt. Mus.*, *N.S.*, **2**, 1–345, 1929.

[11] Kashyap, S. R. and Joshi, A. C., *Lahore District Flora*, Lahore, 1936.

[12] Saxton, W. T. and Sedgwick, L. J., *Rec. Bot. Surv. Ind.*, **6**, 7, 1918.

[13] Blatter, E., *Journ. Bomb. Nat. Hist. Soc.* (Appearing in parts of which more than 26 have been published).

[14] Calder, C. C., Ramaswami, M. S. and Narayanaswami, V., *Rec. Bot. Surv. Ind.*, **11**, 1–195, 1926.

[15] Haines, H. H., *A forest flora of Chota Nagpur*, Calcutta, 1910 ; *List of Trees, shrubs and economic herbs of the S. circle of Central Provinces*, Allahabad, 1916.

[16] Osmaston, A. E., *A forest flora for Kumaon*, Allahabad, 1927.

[17] Kanjilal, P. C., *A forest florz of Philibit, Oudh, Gorakhpur and Bundelkhand*, Allahabad, 1933.

[18] Parker, R. N., *A forest flora for the Punjab, with Hazara and Delhi*, Lahore, 1918, 2nd ed., 1924.

[19] Parkinson, C. E., *A forest flora of the Andamans*, Simla, 1923.

[20] Witt, D. O., *Forest flora of the Berar circle*, 1908 ; *Descriptive list of Trees, Shrubs, Climbers and economic herbs of Northern and Berar circles of C.P.*, 1916.

Various authors have studied critically the species of several genera and described new species. Of these monographic studies Beccari's [1] monographs of Indian Palms, Fyson's [2] species of the Indian *Eriocaulons*, and Blatter's [3] revision of *Butea*, *Terminalia* and other genera, and Blatter, McCann and Bhide's [4] Bombay Grasses are good examples.

Space does not permit giving a complete list, but among others may be mentioned a Weed Manual of the Gwalior State by Kenoyer [5] and lists of exotic plants by Brühl,[6] Kashyap,[7] and Raizada.[8]

V. PALÆOBOTANY.

The publication of the great work entitled 'The fossil flora of the Gondwana system' (1877–86) based chiefly on the work of O. Feistmantel forms the basis of our knowledge of Indian fossil plants. In 1902 Zeiller published a revision of the lower Gondwana or Glossopteris flora, which was followed by a monograph of the group by Newell-Arber, based on the collections available in the British Museum. In a series of contributions (1905–1912) Prof. A. C. Seward published accounts of the newly discovered Glossopteris flora of Kashmir, the upper Gondwana flora, and the Jurassic flora of the Rajmahal hills with its dominant element of fossil Cycads, conifers and ferns. In 1920 Seward and Sahni published a memoir on a revision of Indian Gondwana Plants.

The position of Indian Palæobotany up to 1921 [9] was reviewed by Professor Sahni in his Presidential Address to the Botany section of the Indian Science Congress in Calcutta in that year. Prof. Sahni summed up the position of the study of fossil plants at that time as follows :—

1. The subject of Indian fossil plants was originally treated chiefly from the geological standpoint, and viewed in this light it contributed results that were of value to geologists.

2. The study of the subject from the special view-point of the botanist is an event almost entirely of the present century, but

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[1] Beccari, O., *Ann. Roy. Bot. Gard. Calcutta*, **11**, 1911–14 ; **12**, 1918–21 ; **13**, 1931.

[2] Fyson, P. F., *Journ. Ind. Bot.*, **2**, 133–150, 192–207, 259–266, 307–320, 1921 : *ibid.*, **3**, 12–18, 91–115, 1922-23.

[3] Blatter, E., *Journ. Ind. Bot. Soc.*, **8**, 133–138, 1929 ; *ibid.*, **8**, 245–262, 1929.

[4] Blatter, E., McCann, C. and Bhide, R. K., *Sc. Monograph. Imp. Council Agr. Res.*, **5**, 1–324, 1935.

[5] Kenoyer, L. A., *Weed manual of Gwalior State*, Calcutta, 1924.

[6] Brühl, P., *Journ. Proc. A.S.B.*, *N.S.*, **4**, 603–656, 1908.

[7] Kashyap, S. R., *Journ. Ind. Bot.*, **3**, 68–71, 1922.

[8] Raizada, P., *Journ. Ind. Bot. Soc.*, **14**, 339–349, 1935 ; *ibid.*, **15**, 149–167, 1936.

[9] Sahni, B., *Proc. Ind. Sc. Congr.*, **8**, clii–clxxv, 1921.

even this brief acquaintance from a different 'angle of vision' has shown the importance of the evolutionary aspect.

3. Our knowledge is practically confined to impressions. These, although of great value to those interested in geographical distribution, do not often yield results of morphological value. But the continued investigation of all specimens in which the cuticular or sporangial structure is preserved is bound to be a fruitful line of work.

4. At the same time, the search for petrifactions should be continued with unabated energy, for after all, these are the most useful relics for the students of Botany.

5. The greatest gaps in our knowledge are in the earliest and most recent fossil plants. Any discovery of plants older than the Carboniferous glacial period would be of especial interest : a further search in the Po Series of rocks in Spiti in which Dr. Hayden discovered a few plant-remains, would probably well repay the trouble.

6. It is now time that a systematic description and illustration should be attempted of the accumulated material of the Tertiary and Post-Tertiary plants of India.

From the account of palæobotanical work in India given below it will be seen that a considerable advance has been made in nearly all directions. This account is mainly based on Prof. Sahni's Presidential Address to the Botany section of the Silver Jubilee Session of the Science Congress.

Early Palæozoic Floras

A recent revision of a small Rhacopteris flora from the basal part of the Po Series of Spiti, known as the Thabo stage, has shown that this flora is definitely of Lower Carboniferous age, as opposed to the view of prominent Indian geologists that it was middle Carboniferous.

The Glossopteris Flora

The exact relation of the Gondwana flora to the Ice Age from which it emerged has been a much debated question. In this connection Miss Virkki's [1] recent discovery of a two-winged pollen-grain *Pityosporites antarticus* (which is now regarded as probably belonging to *Glossopteris*) from carbonaceous shale collected by Mr. E. R. Gee at Kathwai, in the Salt Range is of unusual interest. The same spores have now been collected from beds only 1½ feet and 4½ feet above the boulder bed which indicates that in the Salt range at least the Glossopteris flora was contemporaneous with the carboniferous Ice Age.

The Flora of the Rajmahal Series

Large collections from a number of localities in this region have recently been made. These include abundant silicified remains, which has enabled a study of the anatomy of *Tæniopteris*, *Ptilophyllum*, *Williamsonia* and other genera. They have also made it

[1] Virkki, C. (Miss), *Proc. Ind. Acad. Sc. B.*, 6, 428–31, 1937.

possible to recognize, as parts of one and the same plant, leaves, stems, flowers and other detached organs which have long been known under distinct generic names.

The detailed examination of these plant remains suggests that *Tæniopteris spatulata* represents leaves of a cycadean type borne on short cylindrical shoots, which represent younger branches of *Pentoxylon* stems, with a distinctly coniferous type of wood. Similarly, it has been proved that *Ptilophyllum* cf. *Cutchense* were leaves, borne upon stems known as *Bucklandia indica*, which bore flowers of the *Williamsonia* type.

The discovery by Jacob [1] of *Sagenopteris* or leaves recalling *Sagenopteris* in the Rajmahal Flora may be considered as the first discovery of the *Caytoniales* in India. In the same flora Rao [2] has found two-winged pollen grains which may belong to the Caytoniales, though others are probably coniferous.

A peculiar fructification found closely associated with the *Sagenopteris* has been *Sakristrobus*. Another fructification of unknown affinity has been named *Rajmahalia* and provisionally referred to the Bennettitales.

From this same area has been discovered long ago but only recently described, a petrified wood *Homoxylon rajmahalensis*, which is interesting owing to its resemblance to the wood of some fossil Cycads on the one hand and that of some primitive dicotyledons belonging to the modern Magnoliales on the other.

A Wealdean (Lower Cretaceous) flora

Quite recently Dr. Heron and Mr. P. N. Mukherjee have discovered from the Himmatnagar sandstone in the Idar State in Western Rajputana, two widespread genera of Xerophytic ferns, *Matonidium* and *Weichselia*, showing the extension of the Wealdean flora (Cretaceous) into India.

Cretaceous Marine Algæ.

Prof. L. Rama Rao [3] has discovered an algal flora containing members of several existing families of sea weeds in the marine limestones of Niniyur in the Trichinopoly district which has been described by J. Pia.[3] It has been suggested that these algæ lived in the sea towards the close of the cretaceous period.

Tertiary Floras

From the Eocene of Sind, Walton [4] has described a *Triploporella*, a member of the modern family Dasycladaceæ. Some algæ from the Nummulitic beds of Cherrapunji were assigned to *Lithothamnium* by the late Prof. H. C. Dasgupta.[5]

Characeous fruits have been described from Sausar in the Chhindwara District and from the Rajamundry area. In the

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[1] Jacob, K., *Proc. Ind. Acad. Sc. B*, **6**, 73–90, 1937.
[2] Rao, A. R., *Proc. Ind. Sc. Congr.*, **23**, 304, 1936.
[3] Rama Rao, L. and Pia, J., *Palæo. Indica, N.S.*, **21**, 1–49, 1936.
[4] Walton, J., *Rec. Geol. Surv. Ind.*, **56**, 213–19, 1925.
[5] Dasgupta, H. C., *Journ. Dept. Sc. Cal. Univ.*, **8**, 1–10, 1926.

latter area, the Mysore geologists, Narayan Rao and Sripada Rao have discovered several genera of marine algæ, including *Acicularia*, *Neomeris* and *Holosporella*.

Flora of the Deccan Intertrappean Beds

This flora is of unique interest and includes representatives of nearly all the major groups of the plant kingdom. The plants are mostly silicified, and their structure is often very well preserved.

As the result of a fresh study by Sahni, Srivastava and H. S. Rao of many of the old specimens and of fresh collections from a number of new localities (by members of the Geological Survey, by Professors Rode, Agharkar and Parija, by Mr. Shukla of Nagpur and others) the conclusion has been drawn that a flora which included *Nipadites*, the Water Fern *Azolla*, and an overwhelming proportion of palms, could not have flourished in Cretaceous times; it was undoubtedly a younger flora. This has been further supported by the find of the sea weed *Acicularia* from the basal Intertrappeans near Rajamundry by Narayan Rao and Sripada Rao.

As the result of his study of the anatomy of modern palm stems, by a special technique developed by him, Kaul [1] of Lucknow has discovered several criteria, chiefly from the ground tissue, on which a natural classification of palm woods could be based. It has thus been possible to show that the fossil species *Palmoxylon coronatum* is anatomically a *Borassus*, *Palmoxylon mathuri* is a *Bactris*, and that *Palmoxylon sundaram* is a *Cocos*.

Sivalik Flora

The tertiary plant-bearing beds of the Siwalik system have yielded a rich flora of modern aspect, including leaf impressions of angiosperms, petrified wood of dicotyledons and palms, fruits and seeds.

From a revision of the Indian fossil Conifers, Sahni [2] has come to the conclusion that in the Tertiary flora of northern India and Burma there was no trace whatever of this group of plants. Although covering vast areas in the Himalayas today, no trace of them is found even in the younger strata of the Siwalik system, which were deposited in the Pliocene period. They first appear in the overlying Pleistocene beds where the characteristic winged pollen grains of the Abietineæ have been found. It is clear, therefore, that the advent of the Coniferous flora of the Himalayas dates from the end of the Pliocene or even later, when suitable climatic conditions were provided by the elevation of the Himalayas.

Pleistocene Floras

The most interesting of these floras are the Karewa beds of Kashmir which contain a varied assemblage of forest trees and shrubs as well as of aquatic plants, frequently associated with fish-bones and fresh-water shells. In a collection of these from near Baramula the

1 Kaul, K. N., *Proc. Ind. Sc. Congr.*, **22**, 285, 1935.
2 Sahni, B., *Palæontologia Indica, N.S.*, **11**, 1–49, 1928.

late Dr. S. K. Mukherji recognized the leaves of a large number of modern species, while Wodehouse and S. C. Varma have identified the pollen grains of several Conifers and Dicotyledons. They include the pine, deodar, spruce, silver fir, the oak, willow, poplar, box, *Rhododendron*, *Trapa*, *Vallisneria*, *Chara*, etc. Many of the water plants are even now found in the lakes and streams of Kashmir. As many of the Karewa beds have been found at altitudes where these plants could not possibly live today, the conclusion is drawn, that the Pir Panjal range has been upheaved through several thousand feet since the time these plants lived in the Pleistocene Lake of Kashmir. This is in support of the opinion expressed by Godwin Austen long ago.

VI. Applied Botany.

(a) *Forest Botany.*

Research work on forest plants has been confined mainly to the Botany section of the Forest Research Institute, Dehra Dun, since its constitution in 1906. The work of this section has been mainly systematic, mycological and ecological. On the systematic side several forest floras have been published which have been referred to under Angiosperms. A critical study of several genera of forest plants has also been undertaken and the results published from time to time by Messrs. Haines, Hole, Parker, Parkinson and their collaborators chiefly in the Indian Forest Records and Indian Forest Memoirs. Much useful work has been done in connection with the correct identification of timbers and other economic products. The study of the anatomical structure of Indian timbers has been placed on a sound basis by the building up of a collection of Indian timbers linked with corresponding botanical specimens which form the basis of their identity. The publication of the Manual of Commercial Timbers of India (2 vols.) by Pearson and Brown constitutes an important contribution to our knowledge of their anatomy.

The ecological work of the section includes the study of the forest grasses from the ecological side as indicators for soils and forest types, and from the economic side including an investigation of the effect of annual firing and cutting on the composition and stocking of grass lands as sources of fodder and paper pulp materials. Elaborate experiments were conducted to study the 'dying back' of Sal seedlings and it was found to be due to temporary waterlogging of the soil during the rains. The 'Sylviculture of Indian trees' by R. S. Troup in 3 volumes (1921) incorporates a very large amount of information on the autecology of forest species.

The fungal and other diseases of Forest plants have also been studied in this section. Hole investigated the spike disease of Sandal and the diseases of *Pinus excelsa*. He also discovered

Armillaria mellea growing on the spruce fir together with *Fomes annosus*. Since his appointment as Forest mycologist in 1927, K. Bagchee has been studying the heterœcious rusts of Conifers in particular and all Himalayan rusts in general. As the result of his work, the systematic position of a large number of unclassified æcidia has been settled by establishing their relationship with several Puccinias, Uromyces, and Melampsoras. The cytology of several genera has been investigated, which is expected to throw light on the generic grouping of several Melampsorellas.

Other work includes a study of the diseases of Sal (*Shorea robusta*), Shisham (*Dalbergia sissoo*) and other forest species and a study of the mycorrhiza of tropical trees.

An interesting co-operative investigation, in which scientific officers from Dehra Dun and Bangalore, and field officers from the districts have been taking part is the investigation of the spike disease of the Sandal. The work done up to now has shown that the disease is caused by a virus which is transmitted by insect agency. The particular insect concerned in the transmission has not been isolated, but eight species, three Pentatomideæ, two Jassidæ and three Fulgoridæ are suspected in this connection.

(b) *Agricultural Botany.*

The application of Botany to Agriculture has been discussed under three heads (i) Plant breeding, (ii) Plant diseases due to fungi, and (iii) Plant physiology and Biochemistry in the Chapter on the progress of Agricultural Science by Dr. W. Burns and need not, therefore, be repeated.

(c) *Medicinal plants.*

The most important work in this branch of Botany has been the publication of Kirtikar and Basu's work on Indian Medicinal plants in 1918. Although largely a compilation, it has done great service by bringing together in one place all the available information on the subject. The illustrations, also taken from existing sources, provide a good help for the identification of drug plants. The text has recently been revised by E. Blatter, thus bringing it up to date. Nearly 1,400 species have been described and illustrated in this work.

Since 1921, R. N. Chopra of the Calcutta School of tropical medicine has been engaged in a systematic study of the properties of the most important medicinal plants of India. He and his collaborators have investigated the properties of nearly 100 drugs in detail. He has since incorporated the results of his investigations in a book on the 'Indigenous drugs of India' which was published in 1933. Since 1935 he has been engaged in extending his work to a study of the detailed geographical distribution of the drug plants,

and of the poisonous plants and food poisons and has collected an authentic herbarium at the Tropical School of Medicine, Calcutta.

Some work on the same lines was done by Caius and Mhaskar at the Haffkine institute, Bombay; this is now being continued by Dixit.

VII. Plant-geography and Ecology.

Indian botanists have been fairly active in these branches of Botany. Agharkar[1] studied the means of dispersal and the present-day distribution of the Xerophytes and Subxerophytes of N.W. India and traced their origin. Blatter and Hallberg[2] have described the vegetation of the Indian desert on the basis of Warming's formations, and Saxton and Sedgwick[3] have done the same for Gujerat. Kenoyer[4] has made a study of successions in the sub-tropical forests of the central Himalayas, and Dudgeon[5] has made a similar study of the Gangetic plains vegetation. Haines[6] has discussed the Botanical formations occurring within Bihar and Orissa. Dudgeon and Kenoyer[7] have studied the ecology of Tehri-Garhwal. Dudley-Stamp and Lord[8] have described the associations of the riverine tracts of Burma. The ecology of the flora of Sind was studied by Sabnis.[9] Dastur and Saxton[10] have described the ecology of plant communities in the Savannah formations of Gujerat. Burkill[11] has described the Phytogeography of Aborland in his Botany of the Abor Expedition. The forests of Kalimpong have been studied by Cowan.[12] Kashyap[13] studied the vegetation of the Western Himalayas and Western Tibet in relation to their climate. Kashyap[14] also discussed some aspects of the alpine vegetation of the Himalayas and Tibet on the basis of his own observations extending over several years.

Much of the work referred to above is observational and descriptive only. Recently several authors have studied the ecology of individual species experimentally. Hole's work on the

[1] Agharkar, S. P., *Jahrb. Syst. Bot.*, **56**, Beibl, 124, 1–41, 1920.

[2] Blatter, E. and Hallberg, F., *Journ. Bomb. Nat. Hist. Soc.*, **27**, 270–279, 506–519, 1921.

[3] Saxton, W. T. and Sedgwick, L. J., *Rec. Bot. Surv. Ind.*, **6**, 205–323, 1918.

[4] Kenoyer, L. A., *Journ. Ind. Bot.*, **2**, 236–258, 1921.

[5] Dudgeon, W., *Journ. Ind. Bot.*, **1**, 296–324, 1920.

[6] Haines, H. H., *Bot. of Bihar and Orissa*, part 1, 28–70, 1925.

[7] Dudgeon, W. and Kenoyer, L. A., *Journ. Ind. Bot. Soc.*, **4**, 233–285, 1925.

[8] Dudley-Stamp and Lord, L., *Journ. Proc. A.S.B., N.S.*, **19**, 91–100, 1923 : *Journ. Ecol.*, **11**, 129, 1923.

[9] Sabnis, T. S., *Journ. Ind. Bot. Soc.*, **8**, 263–286, 1929.

[10] Dastur, R. H. and Saxton, W. T., *Journ. Ind. Bot.*, **2**, 34–50, 1922.

[11] Burkill, I., *Rec. Bot. Surv. Ind.*, **10**, 1924.

[12] Cowan, J. M., *Rec. Bot. Surv. Ind.*, **12**, 1929.

[13] Kashyap, S. R., *Journ. Ind. Bot. Soc.*, **4**, 327–334, 1925.

[14] Kashyap, S. R., *Proc. Ind. Sc. Congr.*, **19**, 13–53, 1932.